Ecumenical Advocacy Alliance
Food for Life Campaign

Nourishing the World Sustainably: Scaling Up Agro-ecology[1]

This draft discussion paper has been prepared for Rio +20, June 2012. A final report will be available summer 2012. Please send any comments to Christine Campeau, Ecumenical Advocacy Alliance Food Campaign Coordinator, ccampeau@e-alliance.ch

"Abundant life is always life shared with others, empowering the impoverished and strengthening the weak, as Jesus did and promised for all." From *In the Beginning – a theological reflection on agro-ecological farming*, EAA, May 2012

As we enter the second decade of the 21st century, the assumptions of climatic stability, abundant water and cheap energy that continue to fuel modern industrial agriculture can no longer be maintained. Inputs and operations at the heart of industrial agriculture such as agrochemicals, fuel-based mechanization and irrigation are based on dwindling and increasingly expensive fossil fuels. Climate extremes are becoming more frequent and violent and threaten modern monocultures now covering 80% of the 1500 million hectares of global arable land. Although intensive agriculture through the green revolution doubled cereal production in many parts of the world, it destabilizes the natural resource base and drives much of the loss of biodiversity. Moreover, industrial agriculture contributes about 22% of total global greenhouse gas (GHG) emissions (more than the transport sector), damaging the environment and compromising the world's capacity to produce food in the future (Via Campesina, 2009).

Today there are about 1 billion hungry people on the planet[2], but hunger is caused by poverty (1/3 of the world's population lives on less than $2 a day) and inequality (lack of access to land, seeds, etc), not scarcity due to lack of production. At the same time, obesity causes 3.8 million deaths worldwide before the age of 60 and the number of deaths from obesity-related conditions is expected to climb to 5.1

[1] This draft discussion document presents the Ecumenical Advocacy Alliance's views and recommendations for Rio +20 on the need for further recognition of the full range of benefits of agro-ecological methods of food production and the support that is needed to use them on a wider scale. It was written by Dr Miguel Altieri, with assistance from Andrew Kang Bartlett, Carolin Callenius, Christine Campeau, Kristen Elsasser, Paul Hagerman, Gary Kenny, Kato Lambrechts, Jose Pablo Prado, Peter Prove, Nadia Saracini, and Karin Ulmer. Guidance was provided by members of the EAA Food Strategy Group.

[2] FAO's best estimate of the number of hungry people comes from 2010. The methodology FAO uses for calculating the prevalence of hunger is currently under revision, so no estimates were produced for 2011 (FAO and WFP 2010). "The percentage of hungry people is highest in east, central and southern Africa. Around three-quarters of undernourished people live in low-income rural areas of developing countries, principally in higher-risk farming areas. However, the share of the hungry in urban areas is rising. Of the total number of the 925 million chronically hungry people, over half are in Asia and the Pacific and about a quarter are in Sub-Saharan Africa." (See http://www.wfp.org/hunger/faqs).

million people by 2030.[3] In countries such as the United States, this means that the current generation of children could have shorter life expectancies than their parents due to their dietary choices and lifestyles.[4]

Though threatened by advancing climate change, the world currently produces enough food to feed 10 billion people, the population peak expected by 2050 (Holt-Gimenez, 2012). The bulk of industrially produced grain crops is used for biofuels and animal feed. It is also estimated that one-third of all food produced each year is wasted, either at the point of production (post-harvest losses resulting primarily from inadequate infrastructure for food storage, preservation, processing and transportation, education and training) or at the point of consumption (through wasteful consumer habits) (FAO 2011). Therefore the call to double food production by 2050 is based on the assumptions that we will continue to prioritize feeding automobiles and livestock over feeding hungry people and that we will fail to act to reduce food waste.

Fifty percent of the food consumed domestically in the world comes from 350 million small farms cultivated by 1.5 billion smallholders, mostly located in the developing world, and occupying only 20-30% of the arable land (ETC, 2009). Many traditional farming communities and indigenous peoples have over generations developed agricultural systems that can be considered agro-ecologically-based (ETC, 2009). Such traditional farmers domesticated 5,000 crop species and 1.9 million plant varieties, mostly grown without agrochemicals (ETC, 2009). While traditional agricultural knowledge and practice has in many places been lost or atrophied, such small diversified farming systems offer promising models for promoting biodiversity, conserving natural resources, sustaining yield without agrochemicals, providing ecological services and lessons for resilience in the face of environmental and economic change. It is acknowledged that in some contexts, traditional knowledge is showing important vulnerabilities that may, or should, be addressed by new techniques and practices (Toledo and Barrera-Bassols, 2008).

The ensemble of traditional crop management practices used by many resource-poor farmers can lead to the conservation and regeneration of the natural resource base, and can offer a rich resource for the creation of novel agro-ecosystems adapted to local agro-ecological and socioeconomic circumstances. Such traditional techniques tend to be context- and knowledge-intensive rather than input-intensive, but clearly not all are effective or sufficient; therefore modifications and adaptations may be necessary. Since the 1980s, thousands of projects launched by NGOs, farmers' organizations and some academic and research centers reaching hundreds of thousands of farmers, have applied general agro-ecological principles to customize agricultural technologies to local needs and circumstances, improving yields while conserving natural resources and biodiversity. Agro-ecological management systems are "farmer-intensive" and require peoples' participation and need to be tailored and adapted in a site-specific way to highly variable and diverse farm conditions (Uphoff, 2002).

In the midst of multiple global crises affecting food security, the concept and practice of agro-ecology has gained increasing attention worldwide in the last two decades. A recent major international scientific report, the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009), states that in order to feed 9 billion people in 2050, we urgently need to adopt the most effective and sustainable farming systems, and recommend a shift towards agro-ecology

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[3] R. Beaglehole and others, 'Priority action for the non-communicable disease crisis', *Lancet*, vol. 377, No 9775 (2011), pp. 1438-47.

[4] S.J. Olshansky and others, "A potential decline in life expectancy in the United States in the 21st century," *New England Journal of Medicine*, vol. 352, No 11 (2005), p.1143.

as a means of sustainably boosting food production and improving the situation of the poorest people and communities. The report, based on broad consultations with scientists and extensive literature reviews, contends that small-scale farmers can double food production within 10 years in critical regions by using agro-ecological methods. The UN Special Representative for the Right to Food, Olivier de Schutter has compiled evidence demonstrating that agro-ecological approaches can provide enough food for us all (De Schutter 2010). Even the Consultative Group on International Agricultural Research (CGIAR), which historically has promoted input-driven 'Green Revolution' approaches, has recently identified agro-ecology as an approach offering important possibilities for raising productivity in different regions and in diverse social and environmental conditions (CGIAR, 2012). Confronting the future food challenge effectively will require agricultural systems that exhibit high levels of diversity, integration, efficiency, resiliency and productivity – features which characterize agro-ecology (Holt Gimenez and Patel, 2009).

What is 'agro-ecology'?

As an applied science, agro-ecology uses ecological concepts and principles for the design and management of sustainable agro-ecosystems where external inputs are replaced by natural processes such as natural soil fertility and biological control (Altieri, 1995). Agro-ecology takes greater advantage of beneficial on-farm interactions in order to reduce off-farm input use and to improve the efficiency of farming systems. Agro-ecological principles used in the design and management of agro-ecosystems (Table 1) enhance functional biodiversity which is integral to the maintenance of immune, metabolic and regulatory processes key for agro-ecosystem functioning (Gliessman, 1998).

Agro-ecological principles take different technological forms depending on the biophysical and socioeconomic circumstances of each farm or region. Diversification at a within-crop level may mean using a mixture of crop varieties that have different plant heights or different disease tolerance levels. At the within-field level it may be represented by various intercropping plots surrounded by "companion" plants that can deter its common pests. On a landscape level, diversification may occur by integrating multiple production systems such as agroforestry systems, fallow fields, livestock, and forest remnants to create a highly heterogeneous land matrix. Promoted diversification schemes (see 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, antagonism, allelopathy, etc. – essential for the sustainability and productivity of agro-ecosystems. Agro-ecological systems are not intensive in the use of capital, or chemical inputs, but rather 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.

When designed and managed with agro-ecological principles, farming systems exhibit attributes of diversity, productivity, resilience and efficiency (Box 2). Agro-ecological initiatives aim at transforming industrial agriculture partly by transitioning the existing food systems away from fossil fuel-based production towards an alternative agricultural paradigm that encourages local/national food production by small and family farmers based on local knowledge, 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 agro-ecological technologies (Vía Campesina, 2010). Agro-ecological 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 soil, water and biodiversity management regimes, nourished by complex traditional knowledge systems (Koohafkan and Altieri, 2010).

Competing visions on sustainable farming

There are many competing visions on how to achieve new models of a biodiverse, resilient, productive and resource efficient agriculture. Conservation (no or minimum tillage) agriculture, sustainable intensification production, transgenic crops, organic agriculture and agro-ecological 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.

There are alternative farming systems that are significantly different from agro-ecological approaches. For example, sustainable intensification appears to be modified business as usual of capital and input-intensive industrial agriculture with research mainly aimed at major crops (monocropping) and developed in laboratories. Organic farming is not per se sustainable. If organic systems are managed as monocultures that are in turn dependent on external biological and/or botanical (i.e. organic) inputs, they are not based on agro-ecological 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 commoditized, therefore farmers continue to be dependent on input suppliers, cooperative or corporate (Rosset and Altieri, 1997).

Agro-ecologists argue that organic farming systems that do not challenge the monoculture nature of plantations and rely on external inputs and export-led agricultural development, offer little to small farmers who in turn become dependent on external inputs and foreign and volatile markets. Heavy reliance on expensive certification seals have to be seen critically in this regard as well as fair-trade systems that are primarily or only destined for agro-exports.

When one examines the basic attributes that a sustainable production system should exhibit (Box 3), agro-ecological approaches certainly meet most of the main attributes and requirements (Altieri, 2002; Gliessman, 1998; UK Food Group, 2010; Parrott and Marsden, 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 agro-ecological projects are contributing to sustainable livelihoods by improving the natural, human, social, physical and financial capital of target rural communities (Koohafkan et al., 2011).

The spread and productive/food security potential of agro-ecological systems

The first global assessment of agro-ecologically-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 9 million households benefiting from increased food diversity and security. However caution should be exercised when analyzing this data as many of the South American examples that Pretty et al (2003) use are derived from large farms that do not conform fully to agro-ecological principles.

Nevertheless, sustainable agriculture practices reported in the study 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 the 14 projects with roots as main staples (potato, sweet potato and cassava), the 146,000 farms on 542,000 ha increased household food production by 17 t per year (an increase of 150%). Such yield enhancements are a true breakthrough for achieving food security among farmers isolated from mainstream agricultural institutions.

Africa

The IAASTD report on Sub-Saharan Africa provides and refers to a growing body of evidence demonstrating that investing in agro-ecological approaches can be highly effective in boosting production, incomes, food security and resilience to climate change and empowering communities (IAASTD 2009, Christian Aid 2011).

A 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 per cent. In Kenya, maize yields increased by 71 per cent and bean yields by 158 per cent. 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 over time after conversion.

The UK Government commissioned the Foresight Global Food and Farming Futures Project[5], which 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 ha. 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.

Although some of the yield gains reported in the study depended on farmers having access to improved seeds, fertilizers and other inputs, food outputs improved mainly by diversification with a range of new crops, livestock or fish that added to the existing staples 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).

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

[5] The Project was sponsored by the UK Government's Department for Environment, Food and Rural Affairs (Defra) and Department for International Development (DFID). Project findings published on 24 January 2011. See www.webarchive.nationalarchives.gov.uk/ + /http://www.bis.gov.uk/foresight/our-work/projects/current-projects/global-food-and-farming-futures/about-the-project.

and Niger resulting in a total maize production over a five year period of 8 tonnes compared with 5 tonnes obtained under monoculture (UK Government's Foresight Project, 2011). Another agroforestry system in Africa is one dominated by Faidherbia trees, a nitrogen-fixing acacia species indigenous to Africa that improves crop yields and protects crops from dry winds and land from water erosion. In the Zinder Regions of Niger, there are now about 4.8 million hectares of Faidherbia-dominated agro-ecosystems. 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).

Another major innovation in southern Africa is Conservation Agriculture (CA), which is based on three agro-ecological 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 (Pretty et al., 2011). Improved maize yields increase the amount of food available at the household level, but also increase income levels

The productivity impacts and farmer adoption levels of several additional agro-ecological projects in Africa are summarized in Table 3.

There is a growing body of evidence emerging from Africa demonstrating that agro-ecological approaches can be highly effective in boosting production, incomes, food security and resilience to climate change and empowering communities (Christian Aid 2011). The Participatory Ecological Land Use Management (PELUM) illustrates how outreach to smallholders and applying agro-ecological approaches can provide major contributions to equity and poverty eradication.

<u>Asia</u>

Pretty and Hine (2009) evaluated 16 agro-ecological 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 additional productive system components (such as fish in rice, vegetables on dykes).

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 Vietnam 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.[6]

What probably can be considered the largest study undertaken on sustainable agriculture in Asia analyzes the work of MASIPAG, a network of small-scale farmers, farmers' organizations, scientists and non-governmental organizations (NGOs). The study compares findings from 280 full organic farmers, 280 in conversion to organic agriculture and 280 conventional farmers to act as a reference group (Bachmann et al., 2009). Researchers found that food security is significantly higher for organic farmers. Full organic

[6] See (http://sri.ciifad.cornell.edu/countries/cambodia/camcedacimpact03.pdf).

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 that have increased since 2000 in contrast to stagnant or declining incomes for the reference group of conventional farmers. Per hectare net incomes of the full organic farmers are one and a half times higher than those of conventional farmers. On average, they have a positive annual cash balance for households compared to conventional farmers who experience a deficit in the household cash balance. This means the organic farmers are less indebted than their conventional counterparts. The findings of the study summarized in Table 4 show good outcomes particularly for the poorest in rural areas. The livelihoods (defined as net income plus subsistence) of the poorest quarter of organic farmers are one and a half times higher than the income of the poorest conventional farmers. Net income plus subsistence value of crops calculated on a per hectare basis also shows a clear, highly statistically significant advantage for the organic farmers revealing higher productivity in the organic farms.

Latin America

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

An analysis of several agro-ecological field projects in operation during the 1990s (these initiatives now involve almost 100,000 farming families and cover almost 100,000 hectares 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 (Table 5 – Altieri 2009). In fact, most agro-ecological technologies promoted by NGOs improve traditional agricultural yields, increasing output per area of marginal land from 400–600 to 2000–2500 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 1–1.5 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 5150 farmers and close to 9800 hectares, 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 farmers using cover crops minimize soil erosion and weed growth and exhibit positive effects on the soil's physical, chemical and biological properties (Petersen et al 1999). By using cover crop mixtures including legumes and grasses mulch biomass can reach 8000 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 2011).

In Cuba, it is estimated that agro-ecological 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 (Machin et al, 2010, Rosset et al 2011). As shown in Table 6 small farmers using agro-ecological 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 agro-ecological 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 seeds banks, and their exchange through hundreds of seed fairs (*ferias de semillas*) in central and south America, particularly 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. (http://www.swissaid.org.co/kolumbien/global/pdf/campa_a_28.05.08.pdf).

Attention should be paid to how an increasing number of indigenous groups or *cabildos* in the Andean and MesoAmerican countries have adopted agro-ecology 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.

Scaling up agro-ecological innovations: challenges and opportunities

The cases reported above show that in Africa, Asia and Latin America there are many NGO and farmer-led initiatives promoting agro-ecological production that have demonstrated a positive impact on the livelihoods of millions of people living in small farming communities in various countries (Altieri et al 2011). Agro-ecology has consistently proven capable of sustainably increasing productivity and has far greater potential for fighting hunger, particularly during economic and climatically uncertain times that in many areas are becoming the norm (de Shutter 2010).

With so many proven on-farm social, productive and ecological benefits, the relatively limited adoption and dissemination of agro-ecological innovations begs two questions: (1) If agro-ecological systems are so profitable and efficient, why have they not been more widely disseminated and adopted? and (2) how can agro-ecology be multiplied and scaled up?

Resarchers studying agricultural technology adoption and diffusion have identified a number of constraints that discourage adoption and dissemination of agro-ecological practices (Alonge and Martin 1995), ranging 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 (Box 4). In order to further spread agro-ecology 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 agro-ecological 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 better access to local-regional markets, government support such as credit, seeds and agro-ecological technologies. It should also be recognized that a major constraint to the spread of agro-ecology has been that powerful economic and institutional interests have backed research and development for the conventional agroindustrial approach, while research and development for agro-ecology and sustainable approaches has in most countries been largely ignored or even ostracized (Altieri 2002).

The scaling up of agro-ecology is based on a “bottom-up” approach, using and building upon the resources already available: local people, their knowledge and their autochthonous natural resources.

Successfully scaling up agro-ecology depends heavily on human capital enhancement and community empowerment through training and participatory methods that seriously take into account the needs, aspirations and circumstances of smallholders. Most initiatives to scale up agro-ecology have involved capacity building emphasizing training, farmer field schools, on-farm demonstrations, farmer-to-farmer exchanges, exchange visits and other activities. These activities have been the cornerstone of the NGO extension approach, such as the case of Proshika, a local NGO in Bangladesh that reached ten thousand farmers with formal training in ecological agricultural practices. They soon realized however that the issues involved in promoting agro-ecology are complex. There is limited availability of fuel for cooking, which places competing and more urgent demands on manure and crop residues. Encouraging farmers to use green manure crops, compost, rice straw and water hyacinth as alternative methods for developing soil fertility or afforesting farmland to provide fodder and fuel does little to address the structural issues that underline the lack of access of farmers to land, wood, water and other vital resources. Changes in policy that improve access to these resources are therefore necessary to confront the root causes of poverty.

The NGO AS-PTA engaged along with family farmers in southern Brazil in the search for alternatives to conventional maize production. In 2008-2009, one of the driest conventional maize producing area exhibited an average yield loss of 50%. However the producers who had switched to incorporating agro-ecological practices in their production systems (use of local seeds + green manures + rockdust + minimum tillage), experienced smaller losses - around 20%, with significantly lower average production costs. Based on the data collected in the study, an estimate was made on the positive impacts of a hypothetical public program supporting agro-ecological transition in the region. Taking into account a total population of 48,000 farming families, the potential for increases in the regional production of basic grains (maize + beans) was around 170,000 tonnes with average increases of US $563 on the annual income of family farms. Although these represent rough estimates, they highlight the technical and economical potential of scaling up low-cost agro-ecological technologies, thus responding to the financial crisis facing family farming in Southern Brazil, which emerged in the 1990s with the liberalization of agricultural markets. Unfortunately the Brazilian state has opted to allocate ever more funds to programs aimed at modernizing family farming on the basis of the scientific-technological precepts of the Green Revolution. To this end it created and systematically extended the scale of Pronaf (National Family Farming Support Program), a public program that ended up providing easy credit for purchasing agrochemicals and motorized equipment. In this case, as in many other cases all over the world, non-conducive policies undermined the dissemination of agro-ecology.

Approaches for scaling up agro-ecology

<u>Farmer-to-farmer networks</u>

What started as localized agro-ecology efforts in several isolated rural areas expanded to thousands of peasant communities throughout the world. In Latin America, a key factor in agro-ecological expansion was the *Campesino a Campesino (CAC)* movement which is a horizontal process of exchange of ideas and innovations among farmers. It was via the CAC method that soil conservation practices were introduced in Honduras, and hillside farmers adopting the various techniques tripled or quadrupled their yields from 400 kilograms per hectare to 1,200–1,600 kilograms. This tripling in per-hectare grain production has ensured that the 1,200 families that participated in the program have ample grain supplies for the ensuing year. The adoption of velvet bean (*Mucuna pruriens*) which can fix up to 150 kg of nitrogen per ha as well as produce 35 tones of organic matter per year, helped triple maize yields to 2500 kg/ha. Labor requirements for weeding were cut by 75% and herbicides eliminated entirely (Altieri, Funes and Peterson, 2011).

Organized social rural movements such as the international Via Campesina comprising 150 local and national organizations in 70 countries, and the one million families Landless Workers Movement (MST) in Brazil as well as others such as the ANAP in Cuba have massively adopted agro-ecology as a banner of their technological approach to food production. What constitutes the soul of the Cuban agro-ecological revolution, which led to the highest ever food production in the decade after the collapse of the Soviet Union, previously the main supplier of inputs for Cuban farming, was the adoption of agro-ecological methods by 110,000 family farmers (Rosset et al 2011). In less than a decade the active participation of small farmers in the CAC process of agro-ecological innovation and dissemination through farmer-to-farmer models that focus on sharing experiences, strengthening local research and problem-solving capacities, produced a major impact.

One of the best examples of this approach are the Farmer Field Schools (FFS) which consist of a group-based learning process used by a number of governments, NGOs and international agencies collaborating in the promotion of agro-ecological methods. An example of a successful FFS was promoted by the FAO Intercountry Programme for the Development and Application of Integrated Pest Control in Rice in South and South-East Asia launched in 1980. Farmers carried out experiential learning activities that helped them understand the ecology of their rice fields via simple experiments, regular field observations and group analysis. Thousands of farmers reported substantial and consistent reductions in pesticide use and in many cases there was also a convincing increase in yield attributable to the effect of training. IPM Farmer Field School programs, at various levels of development, are now being conducted in over 30 countries worldwide.[7]

NGO led initiatives

Since the early 1980s, hundreds of agro-ecologically-based projects have been promoted by NGOs and church-based groups throughout the developing world, which incorporate elements of both traditional knowledge and modern agricultural science. A variety of projects exist featuring resource-conserving yet highly productive systems, such as polycultures, agroforestry, soil conservation, water harvesting, biological pest control and the integration of crops and livestock, etc. Approaches to training farmers on agro-ecological methods and disseminating best practices encompass a great variety: field days, on-farm demonstrations, training of trainers, farmers cross-visits, etc. Much of the spread of Conservation Agriculture in southern Africa reaching >50,000 farmers has been attained via one or more these methods.

Developing local markets

There are thousands of initiatives throughout the world aimed at closing the circuits of production and consumption via development of local farmers markets and community supported agriculture. One of the most exciting examples is REDE ECOVIDA in southern Brazil, which consists of a space of articulation between organized family farmers, supportive NGOs and consumers whose objective is to promote agro-ecological alternatives and develop solidarity markets that tighten the circle between local producers and consumers, ensuring local food security and keeping the generated wealth in the community (van der Ploeg 2009). Presently Ecovida encompasses 180 municipalities and approximately 2,400 families of farmers (around 12,000 persons) organized in 270 groups, associations and cooperatives. They also include 30 NGOs and 10 ecological consumers' cooperatives. All kinds of agricultural products are cultivated and sold by the Ecovida members, for example vegetables, cereals, fruits, juice, fruit-jelly, honey, milk, eggs and meat. In 2003, sales amounted to 13 750 000 USD; 27 %

[7] See http://www.fao.org/docrep/006/ad487e/ad487e02.htm

of the sales were to free markets, 20 % for export, 19 % to the institutional market and 34 % for other markets like supermarkets, shops, agro industries etc.[8]

Government policies

Governments can launch policies that support and protect small farmers. In Brazil there are about 4.8 million traditional family farmers (about 85 percent of the total number of farmers) that occupy 30 percent of the total agricultural land of the country. Such family 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. One of the many policies of the Ministry of Rural Development (MDA) is the public purchasing programme *Programa de Aquisiçao de Alimentos* (PAA) created in 2003. The program addresses the circumstance that lack of market access for their products creates hardships for a large number of family farms. Family farms are therefore unable to reach their full earning potential. In the scope of four program lines, farmers are given a purchase guarantee for specific quantities at specific prices making their operations more economically viable.[9]

Food sovereignty movements

Organizations linked to Via Campesina advocate for a more radical transformation of agriculture, one guided by the notion that ecological change in agriculture cannot be promoted without comparable changes in the social, political, cultural and economic arenas. The organized peasant and indigenous based agrarian movements (i.e. the Via Campesina) consider that only by changing the export- and investment-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. These movements embrace the concept of food sovereignty, which constitutes an alternative to the current mainstream thinking on food security. The concept behind food sovereignty contrasts with a neo-liberal approach that focuses on international trade to resolve the world's food problems. Instead, it 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 (via Campesina 2010). But with or without government support, major global peasant rural movements have already initiated an agro-ecological revolution and have launched a strategy followed by millions of farmers to strengthen and promote agro-ecological models of food provision in the framework of food sovereignty. Given the expected increase in the cost of fuel and inputs, the agro-ecological strategy also aims at enhancing energy and technological sovereignty (Figure 1). Energy sovereignty is defined as the right for all rural people to have access to or generate sufficient energy within ecological limits from sustainable sources. Technological sovereignty is defined as the capacity to achieve the two other forms of sovereignty by optimizing agrobiodiversity designs that efficiently use local resources and encourage synergies that sponsor the multi-functioning of agro-ecosystems. This new paradigm of the "three sovereignties" gives agro-ecology a greater scope as a tool to determine the minimum acceptable values for food production, biodiversity conservation, energy efficiency, etc., allowing rural communities to assess whether or not they are advancing towards a basic state of food, energy and technological sovereignty in a context of resiliency.

[8] See http://www.ifoam.org/about_ifoam/standards/pgs_projects/pgs_projects/15649.php
[9] See http://www.rural21.com/uploads/media/rural_2011_4_36-39_01.pdf

In addition to promoting capacity building and agro-ecological innovations on the ground, these organizations oppose excessive trade liberalization, which is driving farmers off their land and which is the principal obstacle to local economic development and food sovereignty. Agro-ecology scientific concepts and approaches are compatible with the struggle and vision of rural movements and understand that the significant scaling up of agro-ecology will only be possible by pressuring national governments to take responsibility to support and regulate food markets and just food system and to control multinational companies; in order to ensure that a country retains and creates policy space to realize food sovereignty objectives and develop equitable, broadly owned domestic farm and food policies, and widely adopting agro-ecological methods which respond to the basic and strategic needs of small farmers and consumers, especially the poor.

Agro-ecology and resiliency to climatic change and extremes

Agro-ecological agriculture can increase farmers' resilience to natural disasters and help them adapt to slow onset climate change through:

- **Better soil management:** Sustainable and organic soil and crop management practices, such as low tillage, the planting of cover crops, and application of manure, crop rotations, agroforestry and IPM help to build up nitrogen, organic matter and beneficial micro-organisms in the soil. Better soil structure means fewer problems such as compaction, erosion and nutrient leaching. It also keeps more water in the soil. This is critical for areas of eastern, southern and western Africa, where climate change is already resulting in higher temperatures and lower precipitation.

- **The diversification of production systems**: Observations of agricultural performance after extreme climatic events show that resilience to climate disasters is closely linked to the level of on-farm biodiversity, a major feature of agro-ecological systems. 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 survey, spearheaded by the *Campesino a Campesino* movement, mobilized 100 farmer-technician teams to carry out paired observations of specific indicators on 1,804 neighboring sustainable and conventional farms. The study spanned 360 communities and 24 departments in Nicaragua, Honduras and Guatemala. It was found that sustainable plots had 20 to 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). 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 agro-ecologically 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 agro-ecosystems are able to adapt and resist the effects of climate change. Agroforestry systems are examples of agricultural systems with high structural complexity that have been shown to buffer crops from large fluctuations in temperature (Morais *et al.*, 2006) thereby keeping the crop closer to its optimum conditions. 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)

Crop diversification through multiple cropping enables smallholder farmers to achieve several production and conservation objectives simultaneously reducing risk. Polycultures exhibit greater yield stability and reduced productivity declines during a drought than in the case of 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. Quite 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.

Intensive silvopastoral systems (ISS) for livestock production combine fodder shrubs planted at high densities under trees and palms with improved pastures. Combined benefits of water regulation, favorable microclimate, biodiversity, and carbon stocks in these ISS not only provide environmental goods and services for livestock producers but also greater resilience to climate change. At the El Hatico farm in the Valle del Cauca, Colombia, 2009 was the driest year in a 40-year record, with precipitation dropping by 44% compared to the historical average. Despite a reduction of 25% 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. In response to the extreme weather, the farm had to adjust its stocking rates and increase energy supplementation. In spite of this, the farm's milk production for 2009 was the highest on record with a surprising 10% increase compared to the previous four years. Meanwhile, farmers in other parts of the country reported severe animal weight loss and high mortality rates due to starvation and thirst (Murgueitio et al 2011).

Conclusion/Summary

The solutions for smallholder agriculture advocated by donors, governments and the initiatives of private foundations have tended to center around the promotion of synthetic fertilizers, pesticides and hybrid seeds, which are costly for farmers and often resource depleting and not sustainable nor resilient. This drive for a new 'Green Revolution' has tended to sideline more sustainable, farmer led approaches (APRODEV-PELUM Association 2012). This is unfortunate given that hundreds of projects throughout Africa, Asia and Latin America show convincingly that agro-ecology provides the scientific, technological and methodological basis to assist smallholder farmers enhance crop production in a sustainable and resilient manner, thus allowing them to provide for current and future food needs. Moreover, contrary to projects run by international centers or big NGOs, grassroots agro-ecological initiatives have very low transaction costs and exhibit huge returns on investment.

The evidence is overwhelming. So, why do policy makers and funders not support agro-ecology? The issue seems to be political or ideological rather than evidence or science based; agro-ecological approaches undermine vested interests of powerful commercial companies and their political affiliates who are keen to maintain control by way of an industrial agricultural system. In response, governments and donors continue to ignore agro-ecological approaches and invest in 'lofty' promises of quick-fix solutions that build on external input intensive 'solutions' and proprietary technologies such as transgenic crops and chemical fertilizers. But these have proven not only to pose serious environmental risks but have also demonstrated to be inaccessible and inappropriate to poor and small farmers who play a key role in global food security.

There is an important role for governments to play in providing incentives for farmers to adopt resource-conserving technologies and reviving public agro-ecological research and extension programs suited to the needs and circumstances of smallholder farmers, their associations and networks. National governments need to increase and protect poor people's access to land, seeds, water and other resources as vital pre-requisites for rural food security. All this must be accompanied by initiatives that enable the creation of, and access to, markets that return fair prices for small-scale producers, and protect peasants from global trade policies and dumping that do not safeguard the strategic position of domestic producers in national food systems.

The need for a more enlightened approach to agriculture is long overdue and in fact is the only viable path of food provisioning for humanity to take under current, predicted and difficult climate, energy, financial and social scenarios. Whether the agro-ecological innovations described above are scaled up to reach all the small farmers of a region is not just a matter of political will and governmental actors. It is a societal matter and will largely depend on the ability of citizens and consumers and social movements involved in the agro-ecological revolution to mobilize, form alliances and exert pressure to ensure different food systems – which puts farmers and communities at the centre empowering them to increase access to agro-ecological knowledge, land, seeds, public services, markets, and more. Rural social movements understand that democratizing agricultural food chains and introducing plurality of economic actors are needed to ensure democratic control and plurality in the food chain and to break down the increasing concentration and monopolies in the food chains to restore community controlled food systems. Such actions must be accompanied by the construction of agro-ecological alternatives that suit the needs of small-scale producers and the low-income non-farming population and that oppose corporate control over production and consumption (Vanderploeg 2009). Of key importance will be the direct involvement of farmers and scientists in the formulation of the research agenda and their active participation in the process of technological innovation and dissemination through farmer to farmer models where researchers and extension workers can play a major facilitating role (Altieri and Toledo 2011).

The way forward

For the Ecumenical Advocacy Alliance (EAA), the agro-ecological system offers solutions to many of the current and future problems we are facing. Agro-ecological approaches deliver economic benefits, with increased food production and improved incomes for farmers. They deliver social benefits, including a reduction in poverty (and the social problems that follow from it) and improved resilience to shocks (from changing climate to volatile prices for energy and farm inputs). And agro-ecological systems deliver environmental benefits, including lower resource use on farms, and reduced environmental impacts both on- and off-farm.

In addition, agro-ecology can work in both small and large scale farming, and has been applied by many farming communities around the world. It can be, and already has been scaled up to reach millions of farmers and millions of hectares in Africa, Asia and the Americas.

The EAA wants to encourage increased attention and support to agro-ecology approaches, which so far has received far too little encouragement and support from the main financial drivers of international agricultural development: governments, foundations and private sector agricultural firms. For the most part, their resources continue to support input-intensive agricultural systems that promise quick, but ultimately unsustainable, increases in productivity, and strong profit potential for agricultural input companies and large-scale farms. These farming methods follow the dominant industrial paradigm, are well promulgated over the last century and known and easily understood by most actors based in Europe or North America.

But replicating the monocropping and huge corn fields of Kansas around the world is not desirable nor possible. It is time to challenge our ways of production and consumption and face up to planetary boundaries and limits to productivity.

Farmers, supporters and other civil society organizations that commit themselves to promote and use agro-ecological practices need to be encouraged to continue their efforts, and to collect and disseminate evidence of their successes.

The EAA is committed to work with its own constituencies, in particular as citizens and consumers in affluent societies, to use their purchasing power to shift market demand toward foods produced in a fair and sustainable manner.

The EAA engages with a long-term perspective on agriculture and future generations. The IAASTD approach of considering agriculture's three "bottom lines" can be helpful: agriculture that fosters development will show economic benefits, social benefits and environmental benefits. Broader inclusion of farmers, especially smallholders, in research and policy discussions will help to build understanding and support. Over time, the weight of evidence will shift political will and lead to policies that promote more widespread promotion and adoption of agro-ecological practices.

Tables and Boxes

Figure 1. The three types of sovereignty to be reached by an agricultural community or region by following agro-ecological principles and in the context of a resiliency strategy (Altieri, Funes and Petersen, 2011)

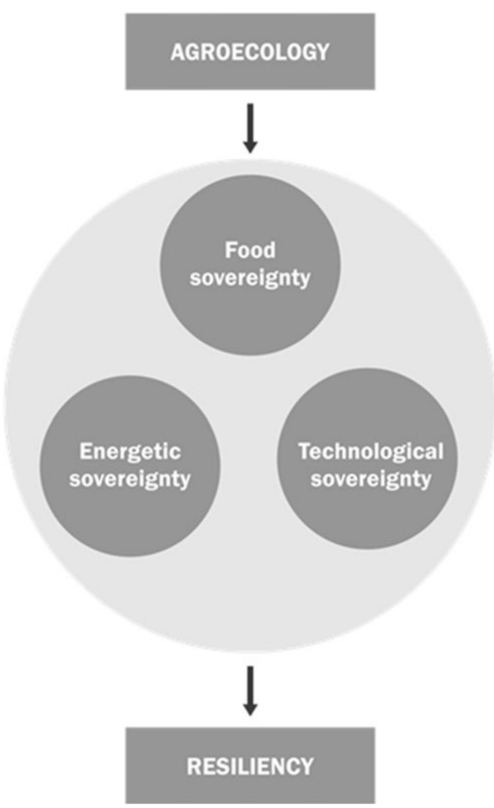

Table 1. Agro-ecological principles for the design of biodiverse, energy efficient, resource-conserving and resilient farming systems

• *Enhance the recycling of biomass*, with a view to optimizing organic matter decomposition and nutrient cycling over time.
• *Strengthen of 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 agro-ecosystem 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.

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?

Table 3. Agro-ecological innovations in Africa: adoption and yield impacts

Embu District, Kenya	1.500 farmers	Nine seeded hole method	Improved land use efficiency, soil fertility and yields. Increased income from 167 to 567 euros/ha
Chebannes Village, Kenya's Rift Valley	> 500 farmers	Agroforestry, mulching, compost	Maize yields from 2,2 to 5,6 t/ha Increased fuelwood and fodder production
Kuna Village, Kenya	180 farmers	Improved groundnut varieties rotated with maize	Increased yields of shelled groundnuts 1,33 – 2,2 t/ha
Slopes of Kilimanjaro, Tanzania	6.500 farmers over 4.200 hectares	Soil and water conservation Contour farming	Increased maize and bean yields > 50% , goat and cow milk production >100%
Karawge District, Tanzania	1.000 farmers in three districts	Organic farming techniques	Increased income up to 130 euros/ha
Tigray, Ethiopia	20.000 farmers	Composting, agroforestry, soil and water conservation	Doubled yield of cereals and pulses
Burkina Faso, Niger	Thousad of farmers in 5.800 has	Zai pits, contour bunding	30-35% yield increases 153 kg p.a. surplus of cereals
Senegal	2.000 Farmers	Stall-fed livestock, compositing, green manures, water harvesting, rock phosphate	Millet and peanut yields increased 75-195% and 75-165% respectively
East Africa	40.000 farmers	Push-pull intercropping system	30-100% > maize yields >milk production and >income
Zimbabwe	3000 farmers	Conservation > maize, sorgum,	> maize, sorgum, millet yields
Malawi and Zambia	Thousands of farmers	Agroforestry with Faidherbia tres	280% increase in maize yields
Madagsacar and Zimbabwe	> 2000 farmers	Conservation Agriculture	Maize yields averaging 3-4 t/ha
Rhotia village Tanzania	> 1000 farmers	Intercopping maize with legume cover crops	4.2 t/ha of maize plus chickpeas and lablab

source: Sustainet partners http://www.sustainet.org/en/information-office.htm and FAO http://www.fao.org/DOCREP/003/Y1730E/Y1730E00.HTM

Table 4. 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.

Table 5. Agro-ecological projects in Latin America

NGO	Characteristics of intervened area	Agro-ecological and socioeconomic constraints	Goals of the agro-ecological strategy	Technical components of the strategy	Impacts and/or achievements
SEMTA (Bolivia)	Pacajes Province, Altiplano (3,500–3,800 m.a.s.l.) Potato, cereals, Andean crops, bovine/ovine cattle, alpacas	Frost, low soil fertility, erosion, deforestation, drought. Generalized poverty, low access to credit, public services, and markets.	Slow environmental degradation process and regenerate productive potential	Organically managed mud-built greenhouses for vegetable production. Terracing, crop rotations for erosion control. Reforestation with native species. Improvement/management of native pastures.	Early production of vegetables under greenhouses resulted in premium prices in nearby La Paz markets, increasing income of participating farmers.
CIED (Puno-Peru)	Altiplano (3,500 m.a.s.l.) Natural pastures (ichu), Andean crops, potato, cattle, camelids	Frost, droughts, flooding, soil and, genetic erosion, low productivity. Poverty and marginalization	Food self-sufficiency, conservation of natural resource base, rescuing of traditional technologies	Rehabilitation of waru-warus and terraces (andenes). Crop rotations. Reintroduction of alpaca. Improved cattle management and sanitation.	Waru-warus ensure potato production in the midst of frost, therefore reducing risks in food production.
IDEAS (San Marcos – Peru	Inter-andean valleys of Cajamarca (18 C, 450 mm rainfall). Potato, maize, cereals, cattle.	Steep slopes, erosion, and seasonal drought. Poverty, low access to good land.	Design of self-sufficient farming system. Rescuing and enriching traditional technology. Soil and water conservation.	Predial design with rotation and polycultures. Organic soil management. Management of small mammals and poultry.	Organic crop production has proved viable, stabilizing yields without use of toxic chemicals.
PTA/CTAQ (Brazil)	Northeastern Brazil, semi-arid tropics. Eight-11 dry months. Perennial cotton, maize, beans.	Rapid organic matter photo-decomposition, low biomass production, low soil fertility, hardpan, and salinity. Poverty, low access to land, marketing problems.	Improve traditional shifting cultivation system (rozado). Offer new productive options for vegetable, fruit, and animal diversification. Water harvesting and conservation. Improved management of animals, in-situ conservation of local germplasm.	Agrosilvopastoral management of catinga (xeric natural vegetation). Design of rotations, agroforestry schemes and polycultures.	Water harvesting techniques and design of drought tolerant cropping systems has enhanced productive potential in semi-arid areas.

CPCC (Paraguay)	Subtropical serrania (600–800 m.a.s.l.) Cassava, maize, peanuts, beans, cotton, sugarcane and rice.	Subtropical drought (4-6 months), low soil fertility. Low income, small landholdings	Design of agroforestry systems, soil conservation and diversification of production.	Community tree nursery. Forest enrichment, soil conservation in slopes, organic soil management.	Agroforestry systems have enhanced production of multiple resources and reverted deforestation
INDES (Argentina)	Dry subtropical area (600 mm). Cotton and subsistence crops (maize, squash, cassava).	Drought, high temperatures, wind erosion, low soil fertility. Poverty, unemployment, lack of credit.	Food self-sufficiency. Optimize use of local resources.	Rationalize cotton based rotations. Improve soil cover to avoid erosion. Use of adapted crop variety.	Diversification schemes have brought new crops into production, challenging dominance of cotton.
CET (Chile)	Chiloe Island Southern Chile (2,000–2,500 mm rainfall). Potato, wheat, pastures	Frost, acid soils, phosphorous deficiency, overgrazing of pastures, genetic erosion. Poverty, marketing problems.	Improve and stabilize productive systems through diversification, use of local resources, rescuing of traditional varieties and technologies, and soil conservation.	In-situ potato genetic community conservation programs. Pasture-based crop rotations. Rotational grazing systems. Silvopastoral systems.	More than 100 traditional potato varieties rescued, with about 250 families involved in in-situ conservation programs.
IDMA (Peru)	Marino watershed	Monoculture, Frost, erosion	Diversify production	Increase crop diversity	Potato-maize yields up. 40% excess production For sale > income
PDRS-GTZ (Peru)	Rio Cascacen Cajamarca	Low wheat and Maize yields	Increase productivity	Intercropping Composting, Soil conservation	200 families > yields 50

Table 6. Two Cuban small-scale farming systems models exhibiting high productivity, high-energy efficiency and high diversity (Funes 2010).

Farm	Cayo Piedra, Matanzas	Del Medio Sancti Spíritus
Area (ha)	40	10
Energy (GJ/ha/year)	90	50.6
Protein (kg/ha/year)	318	434
People fed/ha/year (energy)	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, 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.

Box 1. Temporal and spatial designs of diversified farming systems and their main agro-ecological 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 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.

Box 2. Emerging attributes of agro-ecologically designed and managed farming systems.

Diversity: As diversity increases, so do opportunities for coexistence and for beneficial interactions Between species that can enhance agro-ecosystem sustainability. Greater diversity improves resource-use efficiency in agro-ecosystems. Intermingled crops possess an associated resistance to herbivores as in diverse systems there are a greater abundance and diversity of natural enemies of insect pests (Andow l99l).
Efficiency: Diversified systems tend to be efficient in capturing sunlight, in using rainfall and in Mobilizing and tightly cycling nutrients, exhibiting close efficient energy flows.
Self-sufficiency: A consequence of efficiency and diversity is that agro-ecological systems are self-sufficient requiring mostly inputs of sunlight, rainfall and locally generated nutrients and energy.
Self-regulation: Because of the great diversity of organisms, outbreaks of diseases, insects or weeds that severely damage plants are uncommon. In addition, diverse plants have a number of defense mechanisms that help protect them from attack.
Resiliency: biodiversity enhances the resilience of agro-ecosystems mainly because biodiversity provides “insurance" or a buffer, against environmental fluctuations, as different species respond differently to fluctuations, leading to more predictable ecosystem responses.
Productivity: there is a positive effect of biodiversity on plant biomass production associated with increasing effects of complementarity between plant species translated in better use of soil resources or regulation of pest populations.

Box 3. Requirements of agro-ecologically based agricultural systems (Koohafkan et al., 2011)

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 agro-ecological 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 agro-ecosystem 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

Box 4. Major constraints that limit the dissemination and adoption of agro-ecological approaches by farmers

Farmers' Knowledge and Information Needs**:** Agro-ecological practices are highly complex and management intensive thus adopting them imposes a need for increased learning

Lack of information about agro-ecological practices: one of the reasons for farmers being unable to adopt agro-ecological management techniques is the lack or scarce information regarding economic or technical issues of these technologies. Many farmers lack enough information about economic viability of agro-ecological farming and need to be sure that it represents an economically viable option in order to adopt.

Lack of practical knowledge from researchers and extension agents about agro-ecology: Due to their lack of knowledge, change agents are doubtful of sustainable agriculture and less interested in promoting the concept. Public research and extension agents are increasingly being influences by private interests to promote conventional approaches rather than agro-ecology.

Site specificity of agro-ecology: The conventional technology transfer model breaks down when new management systems need to be tailored and adapted in a site-specific way to highly variable and diverse farm conditions. Agro-ecological principles have universal applicability but the technological forms through which those principals become operational depend on the prevailing environmental and socio-economic conditions at each site. Such site specificity requires local research and innovation.

Lack of farmer's organization: lack of farmers' social networks for collective experimentation and exchange of agro-ecological information is an important constraint for the adoption and siseemnation of socially activating agro-ecological innovations.

Economic barriers: some common economic factors holding farmer from adoption are the cost of adopting, the uncertainty of profitability, cost of making the conversion, loss of productivity during transition, labor demand and perceived increased risk associated with agro-ecological adoption. Even if green markets where to be developed, from the perspective of individual landholders, many of the environmental services provided by agro-ecological systems, such as biodiversity conservation, carbon sequestration, and water conservation, are externalities and therefore do not really act as incentives for adoption as they cannot capture the derived economic benefits.

Biased agricultural policies: national policies not supportive of agro-ecological approaches are largely responsible for sustainable agriculture remaining in the margins. In most countries there is a continuous policy failure in providing the adequate economic environment needed for the transition to agro-ecological production systems. Progressive peasant organizations perceive the promoting of niche (organic and/or fair trade) markets for the rich in the North as exhibiting the same problems of any agro-export scheme that does not prioritize food sovereignty, often perpetuating dependence and at times hunger.

Market failures caused by domestic policies are often a great obstacle for advancement of agro-ecology. Low commodity prices, caused in part by continued subsidization of agriculture in much of the developed world, abate the incentives to invest in agro-ecological innovations. The real prices of agricultural products are so low that it is very difficult for farmers to obtain the capital needed to make the change to sustainable agriculture. Each time food prices increase, a significant number of family and peasant farmers are expelled from the market due to the low cost that they receive for their products and in part due to the high cost of inputs, principally fertilizers. 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 production capacity by the promotion of agroexports and biofuels partly stimulated by government subsidies.

Land tenure issues: lack of access to land or insecure land tenure is an important barrier to adoption of sustainable practices in developing countries. Insecure property rights make it difficult for farmers to adopt agroforestry and soil conservation schemes or to establish contracts for carbon sequestration with farmers who may degrade soil unintentionally

Infrastructural problems: for a more widespread adoption of sustainable practices, countries must invest in appropriate market options, transportation, and communications. In many countries lack of sufficient quantities of organic fertilizers or seeds for cover crops and green manures can be the most difficult barrier to overcome for a widespread of agro-ecology.

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Appendix: Case Studies

Conservation farming in Zimbabwe

Christian Care, a Zimbabwean development agency supported by the Canadian Foodgrains Bank and the United Church of Canada, has been raising awareness and training farmers to adopt conservation farming in order to develop self-sustaining capacities to provide for their food, seeds, nutrition and health needs.

Conservation agriculture reduces soil erosion and improves soil water retention and nutrient recycling. Thus, it improves productivity and resilience, contributing to food security and climate change adaptation. Yields on fields farmed by conservation methods have increased significantly year on year, far outperforming conventionally farmed fields, while requiring fewer chemical inputs and less capital investment.

Conservation farming (CF) has positively impacted many. A farmer from Chirumhanzu stated that "*CF gave me the ability to be as good as everybody else*"[1], while the regional chief for Maware Ward, Chirumhanzu, noted that the key contribution from this CF project was the mulch. He said: "*We have been digging from way back to our ancestors, but the mulching came from Christian Care*"[2]. And indeed, farmers have noticed that with heavy mulch layer, they do not have issues with compaction and weed pressure, resulting in increasing yields year after year.

Essie Mpofu, a lead farmer from Malandu West ward, Nkayi district, also shares her story:

"I have five children and two attend school. I heavily rely on the orchard I have in my homestead and farming as source of livelihood.

I learnt conservation farming from Christian Care and I was taught to use mulch, an essential element needed to keep soil moist. I applied mulch to my plot gradually over time. As a family, we worked hard to achieve at least a 50% mulch cover on our plot. I noticed that because of the mulch, my crop resisted the high heat and experienced less moisture stress than maize under conventional farming, which is very important as we experience drought often.

At the end of my second year, I managed to harvest three times more with these new farming methods compared to conventional farming. With the extra harvest, I donated 10kgs to our own community seed bank and kept some for my own planting in the next season, thereby not depending on the market to buy seed.

I see a lot of improvement in the soil. It has more nutrients and is less affected by erosion. This season, I harvested 480kg from the conservation plot while I only got 20kg from my old plot.

My family is happy with the yields and the quality of crops and neighbours are inspired to take up conservation farming the next year. We are grateful for the knowledge Christian Care has given us."[3]

The success and sustainability of this project is also captured in the following refrain from CF farmers in both Nkayi and Chirumhanzu during a recent evaluation of the project: "*We are never turning back, we'll do CF 'till we die*"[4].

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[1] Conservation Farming in Zimbabwe –Evaluation report, January 2011, p. 19
[2] Conservation Farming in Zimbabwe –Evaluation report, January 2011, p. 22
[3] Peace Mail, Volume 4, Issue 6
[4] Conservation Farming in Zimbabwe –Evaluation report, January 2011, p. 24

Sustainable Livelihoods for Poor Producers (SLIPP), Bangladesh

Traidcraft and their Bangladeshi partner Development Wheel (DEW), together with eight local partners, namely Grameen Manobic Unnayan Sangstha (GRAMAUS), Gono Kallayan Parishad (GKP), Gram Unnoyan Songstha (GRAUS), Unit for Social Advancement (USA), Jana Kollan Prochasta (JKP), Women Development Organization (WDO), Activity for Reformation of Basic Needs (ARBAN) and Sabolambi Unnoan Somiti (SUS) have established the SLIPP project in Northern Bangladesh, one of the poorest parts of the country. After a comprehensive field research, they realized that farmers estimate and apply fertilizers and pesticides erroneously. This is based on the belief that application of more fertilizers will result in better yield. As a result, the level of organic content in soil is at a critical low of 1% with a depleting ground water table. This in turn translated into extremely vulnerable farmers.

To address this issue, the most relevant and viable solution identified was soil testing and the use of compost fertilizer. However, taking into account the availability and multiple use of local resources, farmers were encouraged to create their own compost fertilizer by mixing cow dung with poultry litters, water hyacinth and kitchen waste for example. Indeed, cow dung is also used as cooking fire. SLIPP has proven to be a true success story, a scalable one too, and results went beyond expectations. Badsha Miah is just one of the people whose life changed dramatically for the better as a result of participating in the project:

Badsha is a vegetable farmer from Rajendrapur village, Netrokona. Like many others, he cultivates vegetables to support his family. Badsha attended various training workshops organized by local service providers which, as part of SLIPP, have encouraged farmers both to test their soil in order to define the right amount of fertilizer to be applied and to use organic fertilizer. Based on the results, advice and support, Badsha adapted his practice: he reduced the fertilizer cost by 30% and switched cow dung for organic compost. When harvesting time came, Badsha was very happy and said: "*I did not know about the importance and role of compost fertilizer and soil testing on soil health. Now I know the composting process and application, soil collection procedure and sampling for soil testing, and overall fertilizer management. As a result, this season I got 25% higher production and enhanced profit almost double from the same land!*"

Even better, in addition to selling his vegetables at the market, Badsha also has traders come directly to his field to take products. Moreover, he is planning to increase his production of compost and sell it to neighbouring farmers. Finally, Badsha has become an example for other farmers who have now decided to change their practices as well.