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AGROECOLOGY: ENVIRONMENTALLY SOUND AND SOCIALLY JUST ALTERNATIVES TO THE INDUSTRIAL FARMING MODEL

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Keywords: agroecology, agroforestry systems, traditional agriculture, organic farming, sustainable development, biodiversity

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3.6 Agronomic and Ecological Performance during Transition to Organic Management

The process of conversion of an agroecosystem from a high-input conventional management system to a low-external-input system can be conceptualized as a transitional process with three marked phases (Figure 6).

Increased efficiency of input use as emphasized by traditional integrated pest management.

Input substitution or substitution of environmentally benign inputs for agrochemical inputs as practiced by many organic farmers.

System redesign: diversification with an optimal crop/animal assemblage, which encourages synergism so that the agroecosystem may sponsor its own soil fertility, natural pest regulation, and crop productivity.

For scientists involved in transition research, an important outcome of these studies is the realization that the process of converting a conventional crop production system that relies heavily on synthetic, petroleum-based inputs to a legally certifiable, low-external input, organic system is not merely a process of withdrawing external inputs, with no compensatory replacement or alternative management. Considerable ecological knowledge is required to direct the array of natural flows necessary to sustain yields in a low-input system

Figure 6. The phases in the conversion from conventional monocultures to agroecologically managed biodiverse agroecosystems

Many of the practices currently being promoted as components of Integrated Pest Management (IPM) fall in categories 1 and 2. Both of these stages offer clear benefits in terms of lower environmental impacts as they decrease agrochemical input use and often can provide economic advantages compared to conventional systems. Incremental changes are likely to be more acceptable to farmers as drastic modifications that may be viewed as highly risky or that complicate management. But does the adoption of practices that increase the efficiency of input use or that substitute biologically based inputs for agrochemicals, but that leaves the monoculture structure intact, really have the potential to lead to the productive redesign of agricultural systems? In general, the fine-tuning of input use through IPM does little to move farmers toward an alternative to high input systems. In most cases IPM translates to “intelligent pesticide management” as it results in selective use of pesticides according to a pre-determined economic threshold, which pests often “surpass” in monoculture situations. On the other hand, input substitution follows the same paradigm of conventional farming; 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, many of a corporate nature. Clearly, as it stands today, “input substitution” has lost much of its ecological potential.

System redesign on the contrary arises from the transformation of agroecosystem function and structure by promoting management guided to ensure fundamental agroecosystem processes. Promotion of biodiversity within agricultural systems is the cornerstone strategy of system redesign, as research has demonstrated that higher diversity (genetic, taxonomic, structural, resource) within the cropping system leads to higher diversity in associated biota usually leading to more effective pest control and tighter nutrient cycling.

As more information about specific relationships between biodiversity, ecosystem processes, and productivity in a variety of agricultural systems is accumulated, design guidelines can be developed further and used to improve agroecosystem sustainability and resource conservation.

3.7 Comparisons between Organic and Conventional Systems

In Iowa, researchers compared replicated conventional and organic systems, using identical crop varieties, during the 3-yr transition period and the fourth year following a full rotation of organic corn, soybean, oat, alfafa, to determine which rotation was associated with the lowest risk during transition. Organic feed corn yields were equivalent to conventional yields in the transition years, and in the fourth year, the organic corn yield of 8.1 t/ha in the longest rotation was greater than the conventional corn yield of 7.1 t/ha in the conventional corn-soybean rotation. Organic and conventional soybean yields were similar in the 3 yr of transition. Organic soybean yield of 3.0 t/ha exceeded the conventional yield of 2.7 Mg t/ha in the fourth year of organic production. Pre- and postharvest soil fertility values were responsive to manure application, but few differences between systems were observed. Grass and broadleaf weed populations varied between the organic and conventional systems each year, but the impact on yield was considered negligible. Corn borer (*Ostrinia nubilalis*) and bean leaf beetle (*Ceratoma trifurcata*) populations were similar between systems, with no effect on yield. Researchers concluded that organic grain crops can be successfully produced in the 3 yr of transition to organic, and additional economic benefits can be derived from expanded crop rotations.

In a California study comparing conventional (CNV) and organic (ORG) tomato agroecosystems, where researchers measured various soil chemical and biological properties an root disease severity as well as fruit yield and insect pest damage, CNV and ORG production systems could not be distinguished based on agronomic criteria such as fruit yield and arthropod pest damage levels. However, differences were demonstrated in many soil, plant, disease, and diversity indicators suggesting that the ecological processes determining yields and pest levels in these two management systems are distinct. In particular, nitrogen mineralization potential and microbial and parasitoid abundance and diversity were higher in ORG farms. Differences between the agroecosystems were sufficiently robust to be distinguished from environmental variation and suggest that biological processes compensated for reductions in the use of synthetic fertilizers and pesticides.

A recent study in Maryland confirmed that in intensive conventional tomato production, the use of legume cover crops offers advantages as a biological alternative to commercial fertilizer that reduces soil erosion and loss of nutrients, enhances water infiltration, reduces runoff, and creates a "natural" pest-predator relationship. An important economical outcome of legume cover crop use has been the stemming of disease incidence or severity in diverse crops. The legume hairy vetch (*Vicia villosa*) has been shown to be an effective cover crop and organic mulch for growing tomato plants, resulting in delayed senescence and lesser incidence of foliar diseases. Research aimed at understanding the mechanisms underlying beneficial aspects of legume cover crop revealed a molecular basis for delayed leaf senescence and tolerance to diseases in tomato plants cultivated in a legume (hairy vetch) mulch-based alternative agricultural system. In the hairy vetch-cultivated plants, expression of specific and select classes of genes is up regulated compared to that grown on black polyenthylene mulch (Figure 7). These include N-responsive genes such as *NiR, GS1, rbcL, rbcS*, and *G6PD*; chaperone genes such as *hsp70* and *BiP*; defense genes such as chitinase and osmotin; a cytokinin-responsive gene *CKR*; and gibberellic acid 20 oxidase. Apparently in the hairy-vetch mulched tomatoes, protein products likely complement one another to effect efficient utilization and mobilization of C and N, promote defense against disease, and enhance longevity.

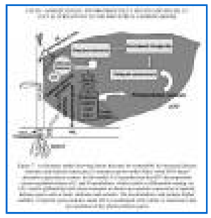

Figure 7. A schematic model showing factors that may be responsible for increased disease tolerance and delayed senescence in tomatoes grown under Hairy vetch (HV)-based alternative agriculture system. In this model, it is hypothesized that HV decomposition causes regulated release of C and N metabolites, which results in differential sensing via CK s and/or gibberellins and whose transport to shoots up-regulates expression of specific defence genes such as basic chitinase and osmotin. The accumulation, and perhaps higher stability, of specific gene products under HV is coordinated with a delay in senescence and up-regulation of key photosynthesis genes.

A study that assessed the sustainability of organic, conventional and integrated apple production systems in Washington State from 1994 to 1999, revealed that all three systems gave similar apple yields (Figure 8), although organic systems performed better in dry years. The organic and integrated systems had higher soil quality and potentially lower negative environmental impact than the conventional system (Figure 9). The results from this study show that organic and integrated apple production systems in Washington State are not only better for soil and the environment than their conventional counterpart but have comparable yields and, for the organic system, higher profits and greater energy efficiency. Although crop yield and quality are important products of a farming system, the benefits of better soil and environmental quality provided by the organic and integrated production systems are equally valuable and often overlooked.

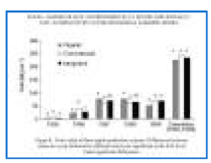

Figure 8. Fruit yields of three apple production systems. Differences between values in a year followed by different letters are significant at the 0.05 level (least significant difference).

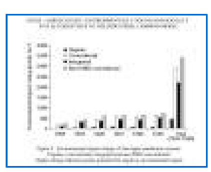

Figure 9**.** Environmental impact ratings of four apple production systems: Organic, conventional, integrated and non-PMD conventional. Higher ratings indicate greater potential for negative environmental impact.

3.8 Healthy soils-Healthy plants

One process that has been observed during the transition to organic farming is that crop losses due to insects and diseases are reduced. Although this view is widespread, there have been surprisingly few attempts to test its validity. Lower pest pressure in organic systems may result from the greater use of crop rotation and/or preservation of beneficial insects in the absence of pesticides. Alternatively, reduced susceptibility to pests may be a reflection of differences in plant health, as mediated by soil fertility management. Many researchers and also practicing farmers have observed that fertility practices that replenish and maintain high soil organic matter and that enhance the level and diversity of soil macro- and microbiota provide an environment that through various processes enhances plant health.

Increasingly, new research is showing that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils. Soils with high organic matter and active soil biological activity generally exhibit good soil fertility as well as complex food webs and beneficial organisms that prevent infection. On the other hand, farming practices that cause nutrition imbalances can lower pest resistance.

Organic soil fertility practices can also provide supplies of secondary and trace elements, occasionally lacking in conventional farming systems that rely primarily on artificial sources of N, P, and K. Besides nutrient concentrations, optimum fertilization, which provides a proper balance of elements, can stimulate resistance to insect attack. Organic nitrogen sources may allow greater tolerance of vegetative damage because they release nitrogen more slowly, over the course of the season and several years. A few studies have demonstrated that the ovipositional preference of a foliar pest can be mediated by differences in soil fertility-management. Thus, the lower pest levels widely reported in organic-farming systems may, in part, arise from plant-insect resistances mediated by biochemical or mineral-nutrient differences in crops under such management.

The integrity of the agroecosystem relies on synergies of plant diversity and the continuing function of the soil microbial community, and its relationship with organic matter. This suggests that the evolution of IPM and integrated soil fertility management (ISFM) must not proceeded separately. Researchers should realize that many pest management methods used by farmers can also be considered soil fertility management strategies and vice-versa. There are positive interactions between soils and pests that once identified can provide guidelines for optimizing total agroecosystem function. For this reason the two fundamental pillars for the conversion process emphasize soil quality through organic methods and plant diversification through habitat management (Figure 10).

3.9 Cuba: a National Experiment on the Conversion to Organic Agriculture

When the "Special Period" was declared in 1991, Cuba was still importing US $80 million in pesticides per year. With adjustments that came with the "special period", pesticide imports were reduced to $30 million. Eleven years of increasingly intensive research and field implementation of biological control and other alternatives has allowed Cuba to undertake one of the most ambitious and successful programs of organic agriculture conversion in the history of any country.

After 1990 Cuba moved on an accelerated basis to replace agrochemicals with locally produced and in most cases biological substitutes. In the area of pest management, this meant the wide use of biopesticides (microbial products) and natural enemies to combat insect pests, complemented with the use of resistant varieties, crop rotations, intrecropping, cover cropping and integration of grazing animals. The reliance on biocontrol agents artesanally produced in about 227 biofactories spread throughout the island has saved Cuba about $6,2 million dollars in pesticide imports. Additional savings also accrue through the massive employment of biofertilizers, compost, natural rock phosphate, green manures and other products for soil fertility enhancement.

Figure 10. The pillars of agroecosystem health.

Undoubtedly, the area in IPM that has received the most attention is the mass rearing and release of natural enemies and the development, mass production, and application of biological insecticides based on insect pathogens. Cuba is one of Latin America's largest producers of biological control agents. While the European Union's annual use of biopesticides reaches about 700 tons per year, Cuba applies some 2,000 tons, all produced nationally. The production of natural biopesticides based on plant extracts is particularly Neem, is also another important development.

- There are various factors that account for the success of Cuban organic farming programs:
- High level of education and significant numbers of professionals directly involved in research and implementation;
- Organized nature of rural Cuban society, especially the spread of cooperatives through new land redistribution programs;
- Broad collaboration, exchange and partnerships among institutions, researchers and farmers;
- Supportive governmental policies;
- Extensive infrastructure of biofactories (CREEs).

Cuba's organic agriculture has partly moved beyond "input substitution" by implementing farm biodiversifaction initiatives and conservation biological control programs such as the use of ants for the control of sweet potato and banana pests and the wide use of crop rotations, polycultures and cover cropping to enhance beneficial biodiversity in agroecosystems.

Cuba's success IPM stories have gained much attention in the rest of Latin America countries, and Cuban experts continuously train and advise personnel from universities, farmers associations and non-governmental organizations on artesanal methods for mass production of biological control agents. Cuba also supplies through the international market many other countries with biopesticidal preparations.

There is no doubt that the current Cuban policy scenario encourages biologically based agricultural production. In practice many farmers are transcending "input substitution" by moving towards an agriculture that maximizes the use of ecological services. Cuba, as many other developing countries facing a strong economic crisis, will most likely continue supporting its agricultural model that not only ensures food security but that is also cost saving and environmentally and health expanding.

3.10 Transitioning Organic Agriculture beyond Input Substitution

Most organic farmers around the world are typically small and/or family farmers, growing diverse enterprises for the local markets, and who see farming as a way of community life closely linked to the rhythms of nature, as the organic food sector grows. However large scale conventional growers have entered into organic production but the practices they follow fall quite short of agroecological ideals. By not limiting the maximum amount of land that a particular farmer or company could certify as organic, organic standers have allowed big corporations to displace small organic farmers. In California, over half the value of organic production was represented by two percent of the growers who grossed over US$500,000 each; growers grossing $10,000 or less comprised 75 percent of all growers and only five percent of the sales. The consolidation of multiple farms, packing plants, and regional hubs under a single corporation requires the adoption of conventional big business practices. This system is excellent for consolidation of wealth and power at the apex of a pyramid, but it is antithetical to the goals of community and local control that were part of the original inspiration of the organic movement.

Structurally and functionally speaking, large-scale commercial organic farms do not differ from conventional farms, as many organic farmers adopt monocultures. These simplified systems lack natural regulatory mechanisms and therefore are highly dependent on external (organic/biological) inputs to subsidize functions of pest control and soil fertility. Adopting such practices and leaving the monoculture intact does little to move towards a more productive redesign of farming systems. Farmers following this regime are trapped in an input substitution process that keeps them dependent on suppliers (many of a corporate nature) of a variety of organic inputs.

A key agroecological strategy to move farms beyond input substitution is to exploit the complementarity and synergy that result from biodiverse farm designs with various combinations of crops, trees, and animals in agroecosystems that feature spatial and temporal arrangements such as polycultures, agroforestry systems and crop-livestock mixtures. In real situations, the exploitation of these interactions involves farming system re-design and management and requires an understanding of the numerous relationships among soils, microorganisms, plants, insect herbivores and natural enemies.

3.11 Enhancing Biodiversity on Organic Farms

A central agroecological principle for organic farmers is to break the non diverse nature of monocultures and thus reduce the ecological vulnerability of their farms by restoring agricultural biodiversity at the field and landscape level. The most obvious advantage of diversification is a reduced risk of total crop failure due to invasions by unwanted species and subsequent pest infestations. Enhanced on-farm biodiversity can contribute to the design of pest-stable agroecosystems by creating an appropriate ecological infrastructure within and around cropping systems (Figure 11). There are hundreds of studies reporting the effects of intercropping, cover cropping, weed management, agroforestry, and manipulation of crop-field border vegetation on pest reduction in diversified agroecosystems.

Flower Strips and Beetle Banks. Several researchers have introduced flowering plants as strips within crops as a way to enhance the availability of pollen and nectar, necessary for optimal reproduction, fecundity and longevity of many natyral enemies of pests. *Phacelia tanacetifolia* Benth. Strips have been used in wheat, sugarbeet (*Beta vulgaris* L. subsp. *vulgaris*), and cabbage (*Brassica oleracia* L.), leading to enhanced abundance of aphidophagous predators, especially syrphid flies, and reduced aphid populations. In England, in an attempt to provide suitable overwintering habitat within fields for predators of cereal aphids, researchers created "beetle banks" sown with perennial grasses such as *Dactylis glomerata* L. and *Holcus lanatus* L.). When these banks run parallel with the crop rows, great enhancement of predators (up to 1500 beetles per square meter) can be achieved in only 2 years.

Flowering Undergrowth in Perennial Cropping. In perennial cropping systems the presence of flowering undergrowth enhances the biological control of a series of insect pests. The beneficial insectary role of *Phacelia* species in apple (*Malus domestica* Borkh.) orchards was well demonstrated by Russian and Canadian researchers more than 30yr ago (Atieri, 1994). In California organic vineyards, the incorporations of flowering summer cover crops (buckwheat [*Fagopyrum esculentum* Moench] and sunflower [*Helianthus annuus* L.]) led to enhanced populations of natural enemies, which in turn significantly reduced the numbers of leafhoppers and thrips.

Weeds as Plant Diversity. In the last 20 years, research has shown that outbreaks of certain types of crop pests are less likely to occur in weed-diversified crop systems than in weed-free fields, mainly due to increased mortality imposed by natural enemies. Crop fields with a dense weed cover and high diversity usually have more predaceous arthropods than do weed-free fields. The successful establishment of several parasitoids has depended on the presence of weeds that provided nectar for the adult female wasps leading to enhanced biological control of particular pests. A recent literature survey by showed that population densities of 27 insect pest species were reduced in weedy crops compared to weed-free crops in a range of systems without compromising crop yields due to competition.

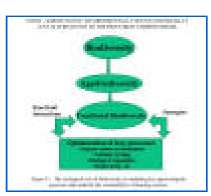

Figure 11. The ecological role of biodiversity in mediating key agroecological processes that underlie the sustainability of farming systems.

Importance of Field Margins. Several entomologists have concluded that the abundance and diversity of predators and parasites within a field are closely related to the nature of the vegetation in the field margins. There is wide acceptance of the importance of field margins as reservoirs of the natural enemies of crop pests, although, depending on plant composition, certain hedgerows may also harbor pests. Many studies have demonstrated increased abundance of natural enemies and more effective biological control where crops are bordered by wild vegetarion from which natural enemies colonize. Parasitism of the armyworm, *Pseudaletia unipunctata* (Hayworth), was significantly higher in maize fields embedded in a complex landscape than in maize fields surrounded by simpler habitats. In a 2-yr study researchers found higher parasitism of larvae of the lepidopteran pest, *Ostrinia nubilalis* (Hubner) by the parasitoid *Eriborus terebrans* (Gravenhorst) in edges of maize fields adjacent to wooded areas, than in field interiors. Similarly, in Germany, parasitism of rape pollen beetle (*Meligethes aeneus* F.) was about 50% at he edge of the fields, while at the center of the fields parasitism dropped significantly to 20%.

Vegetation Corridors and Arthropod Diversity. One way to introduce the beneficial biodiversity from surrounding landscapes into large-scale monocultures is by establishing vegetationally diverse corridors that allow the movement and distribution of useful arthropod biodiversity into the center of monocultures. Reserchers established a vegetational corridor that connected to a riparian forest and cut across a vineyard monoculture in northern California. The corridor allowed natural enemies emerging from the riparian forest to disperse over large areas of otherwise monoculture vineyard systems. The corridor provided a constant supply of alternative food for predators, effectively decoupling predators from a strict dependence on grape herbivores an avoiding a delayed colonization of the vineyard. This complex of predators continuously circulated into the vineyard interstices and established a set of trophic interactions leading to a natural enemy enrichment, which led to lower numbers of leafhoppers and thrips on vines located up to 30 to 40m from the corridor.

4. Moving Ahead

Technological or environmental intentions are not enough to disseminate a more agroecologically-based organic agriculture. There are many factors that constrain the implementation of sustainable agriculture initiatives. Major changes must be made in policies, institutions, markets and research and development agendas to make sure that agroecological alternatives are adopted, made equitably and broadly accessible, and multiplied so that their full benefit for sustainable food security can be realized. It must be recognized that major constraints to the spread of truly sustainable form of farming are the powerful economic and institutional interests that are tying to derail and control the organic industry and its regulations.

The evidence shows that throughout the world, there are many organic agricultural systems that are economically, environmentally and socially viable, and contribute positively to local livelihoods. But without appropriate policy and consumers support, they are likely to remain localized in extent. Therefore, a major challenge for the future entails promoting institutional and policy changes to realize the full potential of a truly organic approach. Necessary changes include the following.

- Increase public investments in agroecological research methods with active participation of organic farmers, thus replacing top-down transfer of standardized technology model with participatory technology development and farmer-centered research and extension, emphasizing principles rather than recipes or technological packages.
- Changes in policies to stop subsidies of conventional technologies and to provide support and incentives for agroecological approaches.
- Appropriate equitable market opportunities including fair market access and expand local farmers markets and CSAs (Community Supported Agriculture or subscription farming) with pricing systems accessible to all.
- Create policies that intervene in the market by opening opportunities for local organic producers (i.e., ordinances that mandate all food served in school and university cafeterias should be organic).
- Democratize and provide flexibility to the certification process, encouraging emergence of no-cost locally adapted certification.
- Include farm size and social-labor considerations in organic standards, and limit certification for operations that leave a large ecological footprint.
- Create GMO free areas.

In summary, major changes must be made in policies, institutions, markets and research to scale-up organic agriculture. Existing subsidies and policy incentives for conventional chemical approaches must be dismantled.

Corporate control over the food system, including the organic industry must also be challenged. The strengthening of local institutional capacity and widening access of farmers to support services that facilitate use of accessible technologies will be critical. Governments and international public organizations must encourage and support effective partnerships between NGOs, local universities, and farmers to achieve success. There is also need to increase rural incomes through local and equitable market opportunities emphasizing fair trade and other mechanisms that link farmers and consumers more directly. The ultimate challenge is to scale-up forms of organic agriculture that are socially equitable, economically viable and environmentally sound. For this to happen, the organic movement will have to engage in strategic alliances with peasant, consumer and labor groups around the world and with the antiglobalization movement. It also needs to secure political representation at local-regional and national levels so that the political will is present in municipal or state governments to implement and expand the goals of a truly sustainable organic agriculture.

5. Conclusions

Most research conducted on traditional and peasant agriculture in the developing world suggests that smallholder systems are sustainably productive, biologically regenerative, and energy efficient, and also tend to be equity enhancing, participative and socially just. In general and when not disrupted, traditional agroecosystems have met the environmental and food requirements of local rural communities by relying on local resources plus human and animal energy, thereby using low levels of input technology.

While it may argued that peasant agriculture generally lacks the potential of producing meaningful marketable surplus, it does ensure food security. Many scientists wrongly believe that traditional systems do not produce more because hand tools and draft animals put a ceiling on productivity. Yields may be low but the cause appears to be more social, not technical. When the subsistence farmer succeeds in providing food, there is no pressure to innovate or enhance yields. Agroecological research shows that traditional crop and animal combinations can be adapted to increase productivity when the biological structuring of the farm is improved and labor and local resources are efficiently used.

New approaches and technologies spearheaded by farmers, NGOs and some local governments around the world are already making a substantial contribution to food security at the household and regional levels. A variety of agroecological and participatory approaches in many countries show very positive outcomes even under adverse conditions. Potentials include raising cereal yields from 50-200%, increasing stability of production through diversification and soil/water management, improving diets and income with appropriate support and spread of these approaches, and contributing to national food security and to exports. Importantly, the agroecological process requires participation and enhancement of the farmers' ecological literacy about their workings of their farms and resources, laying the foundation for empowerment and continuous innovation by rural communities.

Whether the potential and spread of these thousands of local agroecological innovations is realized depends on investments, policies, institutional support, market opportunities, political will and other factors. Major changes need to be made in institutions, research and development, and policies to make sure that agroecological innovations are adopted, made equitable and broadly accessible, and multiplied so that their full benefit for sustainable food security and biodiversity conservation can be realized. Existing subsidies and policies for conventional chemical and transgenic approaches must be dismantled. Corporate control over the food system must also be challenged. Government and international public institutions should encourage and support effective partnerships between NGOs, local universities and farmer organizations in order to assist and empower poor farmers to achieve food security, income generation and natural resource conservation.

Equitable market opportunities must also be developed, emphasizing fair processes and markets and other mechanisms that link farmers and consumers more directly. The ultimate challenge is to increase investment and research in agroecology and scale up projects that have already proved successful to thousands of other farmers. This will generate a meaningful impact on the income, food security and environmental well being of the world's population, especially of the millions of poor farmers as yet untouched by, or already adversely affected by-conventional modern agricultural technology.

In the more industrialized world, organic agriculture is widespread and is growing rapidly. Farmers adopt these systems as a means of increasing income, stabilizing yields, improving soil fertility, reducing dependency on external inputs and enhancing biodiversity and natural resources. These systems are also growing in the South and although data is far from complete, latest estimates of land management according to agroecological principles vary from 15-30 million hectares (equivalent to about 3% of the agricultural land in the South).

There is a tremendous variation among organic growers in regards to diversity, which is primarily regional and crop specific. In annual systems, medium to large scale farmers commonly use spatial and temporal rotations characterized by the planting of crops with different strengths and susceptibilities, but usually incorporating a fertility-enhancing legume crop. In perennial systems cover cropping is the preferred option. Small-scale farmers use more diversified systems such as polycultures, agroforestry and crop-livestock mixtures.

In many cases organic farming systems fall notably short of agroecological principles. In the more market-oriented systems there is a trend toward replacement of agroecological diversification practices with a set of energy and capital intensive "technological packages" and input substitutions, representing a deterioration of organic standards and core values. Although this is a problem facing a small sector of large scale farmers, with proper incentives and agroecological guidance, such systems can evolve towards more diversified less intensive forms of production.

Developing massive training-extension programs to support farmers wishing to convert to agroecological methods will be strategic to scale-up organic agriculture. Solidarious certification as well as access to equitable domestic and export fair markets will be crucial for farmers viability. In this regard, political will that promotes institutional markets allowing farmers to supply schools, hospitals, jails, etc with local and wholesome food will be fundamental. To respond to such opportunities farmers will need to organize in cooperatives able to produce in a timely manner abundant and quality produce. Building up rural infrastructure to permit organic producers to add value and more effectively store and distribute their grains, milk, cheese, fruits, vegetables, etc will prove essential.

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Glossary

Agroecosystem : Communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, fibre, fuel and other products for human consumption and processing. An area used for agricultural production, e.g. a field, is seen as a complex system in which ecological processes found under natural conditions also occur, e.g. nutrient cycling, predator/prey interactions, competition, symbiosis, successional changes, etc

Agroecology : Scientific discipline that provides the basic ecological principles for how to study, design and manage agroecosystems that are both productive and natural resource conserving, Agroecology is the holistic study of agroecosystems, including all environmental and human elements. It focuses on the form, dynamics and functions of their interrelationships and the processes in which they are involved.

Agroforestry : An intensive land-management system that combines trees and/or shrubs with crops and/or livestock on a landscape level to achieve optimum benefits from biological interactions

Biodiversity : Biodiversity in farms refers to all plant and animal organisms (crops, weeds, livestock, natural enemies, pollinaors, soil fauna, etc) present in and around farms and that provide key ecological services. Components of agricultural biodiversity include: (a) productive biota- crops, trees, and animals chosen by farmers that play a determining role in the diversity and complexity of the agroecosystem, (b)resource biota- organisms that contribute to productivity through pollination, biological control, decomposition, etc and (c) destructive biota- weeds, insect pests, microbial pathogens, etc., which farmers aim at reducing through cultural management.

Bioengineering : Construction of a genetically controlled plant or animal by transferring genes from an otherwise genetically incompatible organism to create a novel function or product.

Biological control : The action of parasites, predators, or pathogens in maintaining another organism's population density at a lower average than would occur in their absence. As practiced, biological control can be self-sustaining and distinguishes itself from all other forms of pest control by acting in a density-dependent manner, that is: natural enemies increase in intensity and destroy a larger population of the population as the density of that population increases.

Biological species : Groups of individuals which freely share a common set of genes and are reproductively isolated from other groups so that interbreeding usually cannot occur.

Biotechnology : Combination of biochemistry, genetics, microbiology, and engineering to develop products and organisms of commercial value.

Conventional agriculture : Industrial system of production based on large scale genetically homogeneous monocultures which depend on high inputs of energy and agrochemicals.

Conversion : Transitional process high-input conventional management system to a low-external-input system with three marked phases (a) Increased efficiency of input use through integrated pest management or integrated soil fertility management, (b) Input substitution or substitution of environmentally benign inputs.and (c)System redesign: diversification with an optimal crop/animal assemblage, which encourages synergism so that the agroecosystem may sponsor its own soil fertility, natural pest regulation, and crop productivity

Cultivar **:** Variety of plants produced through selective breeding by humans and maintained by cultivation.

Ecosystem **:** Composite of all the organisms of a given place interacting with the environment.

Ethnoecology **:** The study of the technical knowledge of indigenous peoples, including systems of classification of plants, soil and animals, and the local technologies used to manage natural resources

Genetic diversity **:** In a group such as a population or species, the possession of a variety of genetic traits and alleles that frequently result in differing expression in different individuals.

Genetic engineering **:** Experimental or industrial technologies used to alter the genome of a living cell so that it can produce more or different molecules than it is already programmed to make. The manipulation of genes to bypass normal or asexual reproduction.

Genetic resources **:** The term is essentially synonymous with germ plasm, except that it carries with it a stronger implication that the material has or is seen as having economic or utilitarian value.

Indigenous knowledge **:** Local knowledge about the environment derived through special cognition and perception systems that select for the most adaptive or useful information and successful adaptations are preserved and passed from generation to generation through oral or experimental means. Indigenous peoples knowledge about ecosystems usually result in multidimensional productive strategies (i.e. multiple use ecosystems with multiple species) and these strategies generate (within certain ecological and technical limits) the food self-sufficiency of farmers in a region

Landrace **:** Population of plants, typically genetically heterogeneous, commonly developed in traditional agriculture from many years - even centuries - of farmer-directed selection, and specifically adapted to local conditions.

Legume **:** Plant family characterized by a pea-like flower morphology. Many but not all legumes are nodulated and form nitrogen-fixing symbioses with soil bacteria called rhizobium, bradyrhizobium, and azorhizobium.

Lepidoptera **:** Insect order that includes the moths and butterflies. Larvae of the same.

Monoculture **:** Growth or colony containing a single, pure genetic line of organisms. Genetically uniform line of plants or organisms derived from tissue culture. Production system dominated by one crop variety, void of biodiversity.

Natural enemy : Most insect pests have an array of natural enemies that help in keeping their populations in check. These include predators, parasitoids and pathogens (diseases), all of which occur in agricultural fields but are less abundant in monoculture fields subjected to heavy insecticide treatments as predators and parasites are extremely susceptible to chemical sprays

Nitrogen fixation : Process by which atomic nitrogen is made accessible to plants by conversion to metabolize chemicals like ammonia.

Organic agriculture : Organic farming is a production system that sustains agricultural productivity by avoiding or largely excluding synthetic fertilizers and pesticides. Whenever possible, external resources, such as commercially purchased chemicals and fuels, are replaced by resources found on or near the farm. These internal resources include solar or wind energy, biological pest controls, and biologically fixed nitrogen and other nutrients released from organic matter or from soil reserves

Parasitoid : Most insects parasitic upon other insects are protelean parasites, i.e. they are parasitic only in their immature (larval) stages and lead free lives as adults. They usually consume all or most of the host's body and then pupate, either within or external to the host. The adult parasite emerges from the pupa and starts the next generation anew by actively searching for hosts in which to oviposit. Most adult parasites require food such as honeydew, nectar or pollen and many feed on their host's body fluids

Pathogen : Any agent (fungi. bacteria or virus) that can cause disease and thus lead to crop failure.

Pest : Organism that reaches epidemic proportions in the absence of natural control mechanisms. In agriculture a pest is an insect, pathogen or weed population that has surpassed a pre-established economic threshold.

Polyculture : Simultaneous production of two or more crops in the same space and time. Polycultures usually exhibit enhanced yields which may result from a variety of mechanisms, such as more efficient use of resources (light, water, nutrients) or reduced pest damage. Intercropping, which breaks down the monoculture structure, can provide pest control benefits, weed control advantages reduced wind erosion, and improved water infiltration

Predator : Insects that prey upon other insects and spider mites occur in most orders but primarily in the orders Coleoptera, Odonata, Neuroptera, Hymenoptera, Diptera, and Hemiptera. Predatory insects feed on all host stages: egg, larval (or nymphal), pupal, and adult. From the standpoint of feeding habit, there are two kinds of predators, those with chewing mouth parts (e.g. lady beetles [Coccinellidae] and ground beetles [Carabidae]), which simply chew up and bolt down their prey and those with piercing mouth parts, which suck the juices from their prey (e.g., assassin bugs [Reduviidae], lacewing larvae [Chrysopidae], hover fly larvae [Syrphidae]). The sucking type of feeder often injects a powerful toxin which quickly immobilizes the prey. Many predators are agile, ferocious hunters, actively seeking their prey on the ground or on vegetation, as do beetles, lacewing larvae and mites, or catching it in flight, as do dragonflies and robber flies

Rhizobium : Bacteria able to form nodules with some legumes such as peas, alfalfa, and clover

Scaling up : The dissemination and adoption of agroecological principles over substantial areas by large numbers of farmers and technical staff. In other words, scaling up means achieving a significant increase in the knowledge and management of agroecological principles and technologies between farmers of varied socio-economic and biophysical conditions, and between institutional actors involved in peasant agricultural development.

Sustainable agriculture : A form of agricultural development that leads to an agriculture that is environmentally sound , culturally sensitive, socially just and economically viable

Traditional agriculture : Diverse and locally adapted agricultural systems, managed with time-tested ingenious practices that often lead to community food security and the conservation of natural resources and biodiversity. This peasant strategy of minimizing risk, stabilizes yields over the long term, promotes diet diversity, and maximizes returns under low levels of technology and limited resources.

Variety : Morphologically distinct subtypes of a given species and genus, e.g., a novel variety of corn.

Weed : A plant out of space. Unchecked weed populations may interfere with crop production via competition or allelopathy. At tolerable levels certain weeds can play beneficial role in agroecosystems such as harboring beneficial insects.

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Biographical Sketch

Dr Miguel Altieri leads the Agroecology Program at the University of California, Berkeley. His research group uses the concepts of agroecology to obtain a deep understanding of the nature of agroecosystems and the principles by which they function. Throughout their research and writings they have aided in the emergence of agroecology as the discipline that provides the basic ecological principles for how to study, design, and manage sustainable agroecosystems that are both productive and natural resource conserving, and that are also culturally-sensitive, socially-just and economically viable. In particular, their research has focused on the ways in which biodiversity can contribute to the design of pest-stable agroecosystems. Several studies concentrate on elucidating the effects of intercropping, cover cropping, weed management, and crop-field border vegetation manipulation on pest population density and damage and on the mechanisms enhancing biological control in diversified systems.

Their research has also extended into Latin America where the enhancement of biodiversity in agriculture can help the great mass of resource-poor farmers to achieve year-round food self-sufficiency, reduce their reliance on chemical inputs and develop agroecosystems that rebuild the production capacities of their small land holdings. Their approach has consisted of devising integrated farming systems emphasizing soil and water conservation, natural crop protection, and achievement of soil fertility and stable yields through integration of trees, animals, and crops. Much of this work is conducted through inter-institutional partnerships with NGOs, International Research Centers and Universities including networks such as SANE, ANGOC and CLADES, as well as international organizations such as UNDP and the CGIAR.

To cite this chapter
Miguel A. Altieri, (2007), AGROECOLOGY: ENVIRONMENTALLY SOUND AND SOCIALLY JUST ALTERNATIVES TO THE INDUSTRIAL FARMING MODEL, in *Animal and Plant Productivity*, Ed. Miguel A. Altieri, in *Encyclopedia of Life Support Systems(EOLSS),* Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford ,UK, [http://www.eolss.net.login.ezproxy.library.ualberta.ca] [Retrieved February 28, 2008]

2.4 Biodiversity and its Ecological
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