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

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Contents

2.4 Biodiversity and its Ecological Function in Traditional Agriculture

A salient feature of traditional farming systems is their degree of plant diversity in the form of polycultures and/or agroforestry patterns. This peasant strategy of minimizing risk by planting several species and varieties of crops, stabilizes yields over the long term, promotes diet diversity, and maximizes returns under low levels of technology and limited resources. With crop mixtures, farmers can take advantage of the ability of cropping systems to reuse their own stored nutrients and the tendency of certain crops to enrich the soil with organic matter. Rice monocultures can actually involve a complex system of built-in natural controls and genetic crop diversity involving a number of photoperiod-sensitive rice varieties adapted to differing environmental conditions. Most traditional farmers regularly exchange seed with their neighbors because they observe that any one variety begins to suffer from pest problems if grown continuously on the same land for several years. On the other hand many farmers know that species or genetic diversity in cropping systems confers at least partial resistance to pest attack. Recently, researchers encouraged farmers in ten townships in Yunnan, China, covering an area of 5350 hectares to switch from rice monocultures to planting mixtures of local varieties and hybrids. Enhanced genetic diversity reduced blast incidence by 94% and increased total yields by 84%. By the end of two years, fungicides were no longer required.

The majority of small-scale farmers in Africa practice some form of shifting cultivation involving movement of cultivators from one site to another in search for virgin forests was sustainable given sufficient land and low population pressure. In the bush fallow system, widely practiced in all ecological regions of Sub-Saharan Africa, natural forest, secondary forest or open woodlands are cleared and burnt. Farmers carefully select sites using indicator plants in terms of plant growth and biomass as guides that will produce the best chemical-yielding ash when burnt. Temporary clearings are cultivated until crop yields begin to decline (usually 2-3 growing seasons), then the land is abandoned to return to forest or bush fallow for a period ranging from 4-20 years. During the fallow period, soil fertility regenerates, and weed and pest problems decline. The system depends on natural capital with no external inputs.

Traditional polycultures enhance the abundance of predators and parasites, which in turn prevent the build-up of pests, thus minimizing the need to use expensive and dangerous chemical insecticides. For example, in the tropical lowlands, corn-bean-squash polycultures suffer less attack by caterpillars, leafhoppers, thrips, etc., than corresponding monocultures, because such systems harbor greater numbers of parasitic wasps. The plant diversity also provides alternative habitat and food sources such as pollen, nectar, and alternative hosts to predators and parasites. In Tabasco, Mexico, it was found that eggs and larvae of the lepidopteran pest Diaphania hyalinata exhibited a 69% parasitazation rate in the polycultures as opposed to only 29% rate in monocultures. Similarly, in the Cauca valley of Colombia, larvae of *Spodoptera frugiperda* suffered greater parasitization and predation in the corn-bean mixtures by a series of Hymenopteran wasps and predacious beetles than in corn monocultures.

Tropical agroecosystems composed of agricultural and fallow fields, complex home gardens, and agroforestry plots, commonly contain well over 100 plant species per field, which are used for construction materials, firewood, tools, medicines, livestock feed, and human food period. Examples include multi-use agroforestry systems managed by the Huastecs and Lacandones in Mexico, the Bora and Kayapo Indians in the Amazon basin and many other ethnic groups who incorporate trees into their production systems. Such home gardens are a highly efficient form of land use incorporating a variety of crops with different growth habits. The result is a structure similar to tropical forests, with diverse species and a layered configuration.

In ‘forest-like’ agricultural systems, nutrient cycles are tight and closed. In many tropical agroforestry systems such as the traditional coffee under shade trees (Inga sp., Erythrina sp., etc.) total nitrogen inputs from shade tree leaves, litter, and symbiotic fixation can be well over ten times higher than the net nitrogen output by harvest which usually averages 20 kg ha-1 year-1. In other words, the system amply compensates the nitrogen lost by harvest with a subsidy from the shade trees. In highly co-evolved systems, researchers have found evidence of synchrony between the peaks of nitrogen transfer to the soil by decomposing litter and the periods of high nitrogen demand by flowering and fruiting coffee plants.

Indigenous farmers are able to stagger crop and tree plantings and harvesting to increase overall yields because of the nearly year-round growing conditions. For example, the Bora plant a wide variety of crops, including some 22 varieties of sweet and bitter manioc interspersed among pineapples, fruit trees and minor annual crops. In the Amazon, the Kayapo yields are roughly 200% higher than colonist systems and 175 times that of livestock. In Mexico, Huastec Indians manage a number of agricultural and fallow fields, complex home gardens and forest plots totaling about 300 species. Small areas around the houses commonly average 80-125 useful plant species mostly native medicinal plants.

Not all small farmers rely on spatially diversified systems. For example in southern Brazil, family farmers grow maize, beans, soybeans and wheat as monocultures using low input technologies reaching acceptable yields (2,7 t/ha in maize, 1,5 t/ha in soybeans). Many of the farms have adopted zero tillage systems which have proven to conserve soil, improve organic matter levels without dependence of herbicides which characterizes large-scale monocultural zero tillage. The key to agroecological success has been the design of rotations using cover crops and green manures that provide sufficient t soil cover and lead to organic matter accumulation.

Many small farms integrate animals (cattle, swine, and poultry) into their farming systems. In addition to providing milk, meat, and draft, such animals add another trophic level to the system, making it even more complex. Animals are fed crop residues and weeds with little negative impact on crop productivity. This serves to turn otherwise unusable biomass into animal protein. The need for animal feed also broadens the crop base to include plant species useful for conserving soil and water. Legumes are often planted to provide quality forage but also serve to improve nitrogen content of soils.

2.4.1 Indigenous farming systems as design models

The ensemble of traditional crop management practices used by many resource-poor farmers represents a rich resource for modern workers seeking to create novel agroecosystems well adapted to the local agroecological and socioeconomic circumstances. The techniques used by peasants tend to be knowledge-intensive rather than input-intensive "Slash and burn" or "milpa" is perhaps one of the best examples of an ecological strategy to manage agriculture in the tropics. One of such traditional systems is the "*frijol tapado*" used to produce beans in mid-elevation areas of Central America on steep slopes with high amounts of rainfall where most beans in the region are grown. By maintaining a mosaic of plots under cropping and some in fallow, farmers capture the essence of natural processes of soil regeneration typical of any ecological succession.

The tapado system allows production of beans for both home consumption and cash to supplement meager incomes during times of financial hardship. The cost-effective benefits include: (1) no need for expensive and potentially toxic agriculture chemicals such as fertilizers and pesticides and (2) a relatively low labor requirement. Soil erosion is minimized because of a continuous vegetation cover that prevents exposing the bare ground to heavy rainfall. The rational of "green manures of the "frijol tapado," a contemporary discovery, the use of," has provided an ecological pathway to the intensification of the milpa, in areas where long fallows are not possible anymore due to population growth or conversion of forest to pasture.

After the maize is harvested, the field is abandoned to the spontaneous growth of sown *Mucuna pruriens* leaving a thick mulch layer year-round. One of the main effects of the velvetbean-mulch layer is improved mineral nutrition in the maize crop, cumulative soil fertility and reduced soil erosion. Experiences in Central America show that "mucuna" based maize systems are fairly stable allowing respectable yield levels (usually 2-4 hectares) every year. In particular the system appears to greatly diminish drought stress because the mulch layer helps conserve water in the soil profile. In addition, the mucuna suppresses weeds, either because velvetbean physically prevents them from germinating and emerging or from surviving very long during the velvetbean cycle, or because a shallow rooting of weeds in the litter layer-soil interface makes them easier to control. Data shows that this system grounded in farmers knowledge, involving the continuous annual rotation of velvetbean and maize, can be sustained for at least fifteen years at a reasonably high level of productivity, without any apparent decline in the natural resource base.

Another example involves the push-pull polyculture system developed by ICIPE scientists to control Lepidoptera stemborers. The push –pull system uses plants in the borders of maize fields which act as trap crops (Napier grass and Sudan grass) attracting stemborer colonization away from maize (the push) and two plants intercropped with maize (molasses grass and silverleaf) that repel the stemborers (the pull) (Khan et al., 1998). Border grasses also enhance the parasitization of stemborers by the wasp *Cotesia semamiae*, and are important fodder plants (Figure 5). The leguminous silverleaf (*Desmodium uncinatum*) suppresses the parasitic weed Striga by a factor of 40 when compared with maize monocrop. *Desmodium's* N-fixing ability increases soil fertility; and it is an excellent forage. As an added bonus, sale of *Desmodium* seed is proving to be a new income-generating opportunity for women in the project areas.

Figure 5. The push-pull system, an ingenious polyculture system to regulate the corn borer in Africa.

The push-pull system has been tested on over 450 farms in two districts of Kenya and has now been released for uptake by the national extension systems in East Africa. Participating farmers in the breadbasket of Trans Nzoia are reporting a 15-20 percent increase in maize yield. In the semi-arid Suba district – plagued by both stemborers and striga – a substantial increase in milk yield has occurred in the last four years, with farmers now being able to support increased numbers of dairy cows on the fodder produced. When farmers plant maize together with the push-pull plants, a return of US$ 2.30 for every dollar invested is made, as compared to only $1.40 obtained by planting maize as a monocrop.

2.4.2 Applying Agroecology to Improve the Productivity of Small Farming Systems

Today, throughout the developing world, there are hundreds of examples where small producers in partnership with NGOs and other organizations, have promoted alternative agroecological development projects aimed at enhancing the food security of rural families, conserving and/or regenerating the natural resource base (soil, water and germplasm) and providing some income opportunities to combat poverty. Agroecological approaches have concentrated on a few key interventions:

- Soil conservation and improvement of soil quality;
- More efficient water use, especially in dryland and rainfed areas;
- Pest, disease and weed management using cultural, biological and botanically based strategies, but particularly crop diversity to enhance pest immunity;
- In-situ conservation of agrobiodiversity;
- Design of diversified and integrated farming systems;

Agroecological techniques and designs such as polyculture, cover crops, green manures function as an "ecological turntable" by activating and influencing key components and processes of the agroecosystem. These include:

- Recycling of biomass and balancing nutrient flow and availability.
- Securing favorable soil conditions for plant growth, through enhanced organic matter and soil biotic activity.
- Minimizing losses of solar radiation, air, water and nutrients by way of microclimate management, water harvesting and soil cover.
- Enhancing species and genetic diversification of the agroecosystem in time and space to reduce pest invasion.
- Enhancing beneficial biological interactions and synergisms among agrobiodiversity components to promote key ecological processes and services such as natural pest control and intrinsic soil fertility.

The analysis of dozens of NGO-led agroecological projects show convincingly that agroecological systems are not limited to producing low outputs, as some critics have asserted. Increases in production of 50-100 percent are fairly common with most alternative production methods (Table 3). In some of these systems, yields for crops that the poor rely on most – rice, beans, maize, cassava, potatoes, barley – have been increased by several-fold, relying on labor and know-how more than on expensive purchased inputs and capitalizing on processes of intensification and synergy. Sustainable agriculture practices promoted by various organizations throughout the developing world have lead to 50-100% increases in per hectare food production in rain-fed areas typical of small farmers living in marginal environments.

Table 3. Extent and impacts of agroecological technologies and practices

implemented by NGOs in peasant farming throughout Latin America.

Cuba is an historical example of the potential of agroecological systems to enhance productivity and thus contributing to food security. After the collapse of the socialist bloc when Cuba lost 80% of its import capacity, farms had no fuel for tractors, no fertilizers or pesticides, thus yields declined and per capita caloric intake fell from 1908 calories (in 1989) to 1863 in1994. Through massive development and diffusion of organic techniques (mainly biopesticides and biofertilizers) Cuba's agriculture recovered and by 2000 the caloric level had risen to 2585. Production of tubers and plantains more than tripled and vegetable production doubled from 1994 to 1999. In the same period bean yields increased 60% and cereal production rose from 300, 818 metric tons to 551, 000 tons.

Agroecological interventions raise total farm production significantly through diversification of farming systems, such as raising fish in rice patties or growing crops with trees, or adding goats or poultry to household operations. Data from agroecological field projects show 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. Agroecological approaches also increase the stability of production as seen in lower co-efficients of variance in crop yield with better soil and water management. In fact agroecological interventions significantly decrease the vulnerability of small farmers to natural disasters and other disturbances.

Surveys conducted in hillsides after Hurricane Mitch in Central America showed that farmers using sustainable practices such as cover crops, intercropping, and agroforestry suffered less damage than their conventional neighbors. The survey, spearheaded by the *Campesino a Campesino (farmer to farmer)* movement, mobilized 100 farmer-technician teams and 1,743 farmers to carry out paired observations of specific agroecological indicators on 1,804 neighboring, sustainable and conventional farms. The study spanned 360 communities and 24 departments in Nicaragua, Honduras and Guatemala. Sustainable plots had 20% to 40% more topsoil, greater soil moisture, less erosion and experienced lower economic losses than their conventional neighbors. These data are of great significance to resource-poor farmers living in marginal environments and should provide the basis for an NRM strategy that privileges the temporal and spatial diversification of cropping systems as this leads to higher productivity and likely to greater stability and ecological resiliency. In general, data shows that over time agroecological systems exhibit more stable levels of total production per unit area than high-input systems; produce economically favorable rates of return; provide a return to labor and other inputs sufficient for a livelihood acceptable to small farms and their families; and ensue soil protection and conservation as well as enhanced biodiversity.

2.4.3 Current Limitations to the widespread use of Agroecology

As observed in Table 4, there are many factors that constraint the implementation of sustainable agriculture initiatives. A key obstacle to the use of agroecology is the demand for specificity in its application. Field practitioners must have more diversified information on ecology and on agricultural and social sciences in general. Today's agronomy curricula focused on applying the "Green Revolution" technological kit, is simply unfit to deal with the complex realities facing small farmers. The high variability of ecological processes and their interactions with heterogeneous social, cultural, political, and economic factors generate local systems that are exceptionally unique. When the heterogeneity of the rural poor is considered, the inappropriateness of technological recipes or blueprints becomes obvious. The only way that the specificity of local systems- from regions to watersheds and all the way down to a farmer's field – can be taken into account is through site-specific NRM. This does not mean however, that agroecological schemes adapted to specific conditions may not be applicable at ecologically and socially homologous larger scales. What implies is the need to understand the principles that explain why such schemes work at the local level, and later applying such principles at broader scales. NRM site-specificity requires an exceptionally large body of knowledge that no single research institution can generate and manage on its own. This is one reason why the inclusion of local communities at all stages of projects (design, experimentation, technology development, evaluation, dissemination, etc.) is a key element in successful rural development. The inventive self-reliance of rural populations is a resource that must be urgently and effectively mobilised.

Table 4. Key constrains to implementing sustainable agriculture partnerships (modified from Thrupp, L.A., 1996. New Partnerships for sustainable agriculture. World Resources Institute, Washington, DC.

Major changes must be made in policies, institutions, 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 a major constraint to the spread of agroecology has been that powerful economic and institutional interests have backed research and development for the conventional agroindustrial approach, while research and development for agroecology and sustainable approaches has been largely ignored or even ostracized. Only in recent years has there been growing realization of the advantages of alternative agricultural technologies.

The evidence shows that sustainable agricultural systems can be both economically, environmentally and socially viable, and contribute positively to local livelihoods. But without appropriate policy 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 potential of the alternative approaches. Necessary changes include:

- Increasing public investments in agroecological – participatory methods;
- Changes in policies to stop subsidies of conventional technologies and to provide support for agroecological approaches;
- Improvement of infrastructure for poor and marginal areas;

- Appropriate equitable market opportunities including fair market access and market information to small farmers;
- Security of tenure and progressive decentralization processes;
- Change in attitudes and philosophy among decision-makers, scientists, and others to acknowledge and promote alternatives;
- Strategies of institutions encouraging equitable partnerships with local NGOs and farmers;
- Replace top-down transfer of technology model with participatory technology development and farmer centered research and extension.

2.4.4 Scaling up of Agroecological Innovations

Throughout Africa, Asia and Latin America there are many NGOs involved in promoting agroecological initiatives that have demonstrated a positive impact on the livelihoods of small farming communities in various countries. Success is dependent on the use of a variety of agroecological improvements that in addition to farm diversification favouring a better use of local resources, also emphasise human capital enhancement and community empowerment through training and participatory methods as well as higher access to markets, credit and income generating activities. Pretty et al (2003) analysis point at the following factors as underlying the success of agroecological improvements:

- Appropriate technology adapted by farmers' experimentation;
- Social learning and participatory approaches;
- Good linkages between farmers and external agencies, together with the existence of working partnerships between agencies;
- Presence of social capital at local level.

In most cases, farmers adopting agroecological models achieved significant levels of food security and natural resource conservation. A key challenge now is how to scale-up these initiatives to enable wider impact. For the purposes of this paper, scaling up is defined as 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.

One important factor limiting the spread of agroecological innovations is that for the most part NGOs promoting such initiatives have not analyzed or systematized the principles that determined the level of success of the local initiatives, nor have been able to validate specific strategies for the scaling-up of such initiatives. A starting point therefore should be the understanding of the agroecological and socio-economic conditions under which alternatives were adopted and implemented at the local level. Such information can shed light on the constraints and opportunities farmers to whom benefits should be expanded at a more regional level are likely to face.

An unexplored approach is to provide additional methodological or technical ingredients to existing cases that have reached a certain level of success. Clearly, in each country there are restraining factors such as lack of markets, and lack of appropriate agricultural policies and technologies which limit scaling up. On the other hand, opportunities for scaling up exist, including the systematization and application of approaches that have met with success at local levels, and the removal of constraining factors. Thus scaling up strategies must capitalize on mechanisms conducive to the spread of knowledge and techniques, such as:

- The strengthening of producers' organizations through alternative marketing channels. The main idea is to evaluate whether the promotion of alternative farmer-led markets constitute a mechanism to enhance the economic viability of the agroecological approach and thus provide the basis for the scaling-up process.
- Development of methods for rescuing/collecting/evaluating promising agreocological technologies generated by experimenting farmers and making them known to other farmers for wide adoption in various areas. Mechanisms to disseminate technologies with high potential may involve farmer exchange visits, regional-national farmer conferences, and publication of manuals that explain the technologies for the use by technicians involved in agroecological development programs.
- Training of government research and extension agencies on agroecology in order for these organizations to include agroecological principles in their extension programs.
- Development of working linkages between NGOs and farmers' organizations. Such alliance between technicians and farmers is critical for the dissemination of successful agroecological production systems emphasizing biodiversity management and rational use of natural resources.
- More effective farmers organizations, research-extension institutional partnerships; exchanges, training, technology transfer and validation in the context of farmer to farmer activities, enhanced participation of small farmers in niche markets, etc., are all important requirements for the scaling up of agroecological innovations .

From their worldwide survey of sustainable agriculture initiatives, Pretty et al (2003) concluded that if sustainable agriculture is to spread to larger numbers of farmers and communities, then future attention needs to focus on:

- Ensuring the policy environment is enabling rather than disabling;
- Investing in infrastructure for markets, transport and communications;
- Ensuring the support of government agencies, in particular, for local sustainable agricultural initiatives;
- Developing social capital within rural communities and between external agencies.

The main expectation of a scaling-up process is that it should expand the geographical coverage of participating institutions and their target agroecological projects while allowing an evaluation of the impact of the strategies employed. A key research goal should be that the methodology used will allow for a comparative analysis of the experiences learned, extracting principles that can be applied in the scaling-up of other existing local initiatives, thus illuminating other development processes.

2.5 Outlook and Prospects

Small farmers located in marginal environments in the developing world can produce much of their needed food. The evidence is conclusive: new approaches and technologies spearheaded by farmers, NGOs and some local governments around the world are already making a sufficient contribution to food security at the household, national, 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 to 200 percent, increasing stability of production through diversification, improving diets and income, contributing to national food security and even to exports and conservation of the natural resource base and agrobiodiversity.

Whether the potential and spread of these thousands of local agroecological innovations is realized depends on several factors and actions. First, proposed NRM strategies have to deliberately target the poor, and not only aim at increasing production and conserving natural resources, but also create employment, provide access to local inputs and output markets (Table 5). New strategies must focus on the facilitation of farmer learning to become experts on NRM and at capturing the opportunities in their diverse environments.

Table 5**.** Elements and contributions of an appropriate agroecological strategy (Uphoff, Norman (ed.) 2002. Agroecological Innovations: Increasing Food Production with Participatory Development. Earthscan Publications Ltd., London).

Second, researchers and rural development practitioners will need to translate general ecological principles and natural resource management concepts into practical advice directly relevant to the needs and circumstances of small-holders. The new pro-poor technological agenda must incorporate agroecological perspectives. A focus on resource conserving technologies, that uses labour efficiently, and on diversified farming systems based on natural ecosystem processes will be essential. This implies a clear understanding of the relationship between biodiversity and agroecosystem function and identifying management practices and designs that will enhance the right kind of biodiversity which in turn will contribute to the maintenance and productivity of agroecosystems.

Technological solutions will be location specific and information intensive rather than capital intensive. The many existing examples of traditional and NGO-led methods of natural resource management provide opportunities to explore the potential of combining local farmer knowledge and skills with those of external agents to develop and/or adapt appropriate farming techniques.

Any serious attempt at developing sustainable agricultural technologies must bring to bear local knowledge and skills on the research process. Particular emphasis must be given to involving farmers directly in the formulation of the research agenda and on their active participation in the process of technological innovation and dissemination. The focus should be in strengthening local research and problem-solving capacities. Organizing local people around NRM projects that make effective use of traditional skills and knowledge provides a launching pad for additional learning and organizing, thus improving prospects for community empowerment and self-reliant development.

Third, major changes must be made in policies, institutions, and research and development 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. Existing subsidies and policy incentives for conventional chemical approaches must be dismantled. Corporate control over the food system must also be challenged. The strengthening of local institutional capacity and widening access of farmers to support services that facilitate use of technologies will be critical Governments and international public organizations must 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.

There is also need to increase rural incomes through interventions other than enhancing yields, such as complementary marketing and processing activities. Therefore equitable market opportunities should also be developed, emphasizing fair trade 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 proven 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 yet untouched by modern agricultural technology.

3. Organic Agriculture in the Industrial World

3.1 Global Extent

Organic agriculture is practiced in almost all countries of the world, and its share of agricultural land and farms is growing. The total organically managed area is more than 24 million hectares world-wide. Australia/Oceania holds 42 percent of the world's organic land, followed by Latin America (24.2 percent) and Europe (23 percent). The distribution of the area and farms under organic management for each continent is shown in Figure 5. Oceania and Latin America concentrate much of the land under organic management, but this is due to the fact that extensive organic livestock systems dominate in Australia (about 10 million hectares) and in Argentina (almost 3 million hectares). Europe and Latin America have the highest numbers of organic farms, and in Asia and Africa organic farming is growing and both regions are characterized by small farms (Table 6).

Table 6. Organic agricultural land and farms in different regions of the world.

In Europe organic agriculture is increasing rapidly. In Italy there are about 56,000 organic farms occupying 1.2 million hectares. In Germany alone, there are about 8,000 organic farms occupying about 2 percent of the total arable land and in Austria about 20,000 organic farms account for 10 percent of total agricultural output. In the UK the organic market is displaying growth rates of 30-50% per annum.

Although in the USA organic farms occupy 0.25 percent of the total agricultural land, organic acreage doubled between 1992 and 1997 and in 1999 the retail organic produce industry generated $6 billion in sales. In California, organic foods are one of the fastest-growing segments of the agricultural economy, with retail sales growing at 20-25 percent per year for the past six years.

Cuba is the only country undergoing a massive conversion to organic farming, promoted by the drop of fertilizer, pesticide, and petroleum imports after the collapse of trade relations with the Soviet bloc in 1990. By massively promoting agroecological techniques in both urban and rural areas, productivity levels in the island have recovered substantially.

3.2 Differences between Organic and Conventional Agriculture

Organic farming is a production system that sustains agricultural productivity by avoiding or largely excluding synthetic fertilizers and pesticides. 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 form soil reserves. Thus organic farmers rely heavily on the use of crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insect pests, weeds, and diseases. Most small and medium size organic farmers feature legume-based rotations, use of compost and a series of diversified cropping systems such as cover crops or strip cropping, including crop-livestock mixtures. Research shows that these systems exhibit acceptable yields, conserve energy, and protect the soil while inducing minimal environmental impact.

In contrast, conventional farming characterized by monoculture systems are heavily dependent on the use of synthetic fertilizers and pesticides. Although such systems are productive and able to furnish low-cost food, they also bring a variety of environmental effects such as pesticide pollution, soil erosion, water depletion and biodiversity reduction. Increasingly scientists, farmers, and the public in general have questioned the sustainability of modern agrochemically-based agriculture. The most important difference between organic farming and conventional agriculture is that organic farmers avoid or restrict the use of chemical fertilizers and pesticides in their farming operations, while conventional farmers may use them extensively. A large number of organic farmers do use modern machinery, recommended crop varieties, certified seed, sound live-stock management. Clearly there are sharp contrasts between organic and conventional agriculture (Table 7).

Table 7. Characteristics of conventional and organic farming.

3.3 Comparison of Productivity between Conventional and Organic Systems

Research has shown that organic farms can be as productive as conventional ones, but without using agrochemicals. They also consume less energy and save soil and water. In 1989 the National Research Council wrote up case studies of eight organic farms that ranged from a 400-acre grain/livestock farm in Ohio to 1,400 acres of grapes in California and Arizona. The organic farms' average yields were generally equal to or better than the average yields of the conventional high-intensity farms surrounding them-once again showing they could be sustained year after year without costly synthetic input.

Three kinds of experimental systems have been tested side by side for nearly two decades at the Farming Systems Trial at the Rodale Institute, a nonprofit research facility near Kutztown, Pennsylvania. One system is a standard high-intensity rotation of corn and soybeans in which commercial fertilizers and pesticides have been used. Another is an organic system in which a rotation of grass/legume forage has been added and fed to cows, whose manure is then returned to the land. The third is an organic rotation in which soil fertility has been maintained solely with legume cover crops that have been plowed under. All three kinds of plots have been equally profitable in market terms. Corn yields have differed by less than 1 percent. The rotation with manure has far surpassed the other two in building soil organic matter and nitrogen, and it has leached fewer nutrients into groundwater. During the record drought of 1999, the chemically dependent plots yielded just sixteen bushels of soybeans per acre; the legume-fed organic fields delivered thirty bushels per acre, and the manure-fed organic fields delivered twenty-four bushels per acre.

In what must be the longest-running organic trial in the world-150 years-England's Rothamsted Experimental Station (also known as the Institute of Arable Crops Research) reports that its organic manured plots have delivered wheat yields of 1.58 tons per acre, compared to synthetically fertilized plots that have yielded 1.55 tons per acre. The manured plots contain six times the organic matter found in the chemically treated plots. FIBL scientists in Central Europe conducted a 21-year study of the agronomic and ecological performance of biodynamic, organic, and conventional farming systems They found crop yields to be 20% lower in the organic systems, although input of fertilizer and energy was reduced by 31 to 53% and pesticide input by 978%. Researchers concluded that the enhanced soil fertility and higher biodiversity found in organic plots rendered these systems less dependent on external inputs.

3.4 Organic Agriculture and Biodiversity

Most practitioners of organic agriculture believe that organic farms have positive impacts on biodiversity and that farmland under organic agriculture does not exhibit the dramatic declines of many animal species as observed in areas dominated by conventional agriculture. In a recent survey of the literature, 76 published studies report that species abundance and/or richness, across a wide-range of taxa, was higher on organic farms than on locally representative conventional farms (Table 8). Of particular importance from a conservation perspective is that many of these differences apply to species known to have experienced declines in range and/or abundance as a consequence of past agricultural intensification, a significant number of which are now the subject of direct conservation legislation (e.g. skylark, lapwing, greater and lesser horseshoe bat, corn buttercup *Ranunculus arvensis* and red hem-nettle are all UK government Biodiversity Action Plan species). These biodiversity benefits are likely to derive form the specific environmental features and management practices employed within organic systems, which are either absent or only rarely utilized in the majority of conventional systems. Most of the features and practices listed in Table 9 encourage habitat heterogeneity, floral diversity, alternative food and dispersal considers all aspects known to benefit invertebrate and vertebrate biodiversity across a range of taxa.

Table 8. Summary of the effects of organic farming on individual taxon, in comparison to conventional (Hole et al., 2005).

The FIBL studies in central Europe showed that organic farming allows the development of a relatively diverse weed flora. Nine to 11 weed species were found in organically managed wheat plots and one species in conventional plots. Between 28 and 34 carabid species were found in the organic systems and 22 to 26 species in the conventional system. Some specialized and endangered species were present only in the organic systems. Apart from the presence and diversity of weeds, direct effects of pesticides and the density of the wheat crop stand are most likely influencing arthropod activity and diversity. One of the particularly remarkable findings, was a strong and significant increase in soil microbial diversity in the organic systems, which in term mediated enhanced soil fertility in low-input fields.

In the past decade a growing number of farmers are finding that local agricultural operations can provide critical habitat for wildlife. In North America remnant prairies, woodlands, riparian forests, hedges, etc. are being restored to bring back wildlife to crop fields. In the Sky Islands region of the south western USA, farmers and conservationists have been working for over a decade to develop land use plans to connect protected wilderness through corridors that provide "stepping stones" for pollinators and natural enemies, and offer safe passage for large mammals to move through the landscape. In the midst of California's Industrial agriculture Yolo County, John and Marsha Anderson have restored seasonal wetlands and native vegetation strips along irrigation canals in their 200 acre farm. Two decades later, beavers, carnivores, dozens of bird species and beneficial insects now inhabit the farm, therefore contributing positively to the farm's output.

Table 9. Features and management practices of OA likely to positively input biodiversity.

3.5 Agroecological Features of Organic Farming Systems

As a general rule, organic farming systems tend to minimize energy and resource use, by recycling resources within the farming system, or at least by using resources found near the farm and by enhancing biodiversity which in turn mediates ecological functions rush as pest regulation soil fertility and productivity. From a technical viewpoint, the basic components of a sustainable organic systems are (1) use of cover crops, mulches, and no-till practices a effective soil an water-conserving measures; (2) promotion of soil biotic activity through the regular addition of organic matter such as manure and compost; (3) use of crop rotations, crop/livestock mixed systems, agro-forestry, and legume-based intercropping for nutrient recycling; and (4) encouragement of biological pest control agents through introduction and/or conservation of natural enemies via habitat management and crop diversification.

Through the adoption of such practices, organic farmers aim to:

- buildup of soil organic matter and soil biota;
- minimization of pest, disease and weed damage;
- conservation of soil, water, and biodiversity resources;
- long-term agricultural productivity;
- optimal nutritional value and quality of produce;
- create an aesthetically pleasing environment.

Organic carbon is the central element of organic crop production systems, and the soil ecological community it feeds modulates nutrient retention and release, soil structure, and even resistance to many diseases and insects and even weeds. Legume based crop rotations and cover crops are agroecological management strategies which provide the source of the vast bulk of organic carbon inputs needed for the desired soil microbial community and adequate nutrient pool.

Organic farming systems are effective in sequestering carbon in soils and in biomass. CO2 emissions per hectare of organic agriculture systems are 48 to 66 percent lower than in conventional farms. Studies revealed that CO2 emissions of German organic farms to be 0.5 tones of CO2 per hectare whereas in conventional agriculture the amount was 1,3 tons, a difference of 60 percent . The main effects of organic agriculture that are responsible for this difference are:

- maintenance and increase of soil fertility by the use of farmyard manure;
- omission of synthetic fertilizers and synthetic pesticides;
- lower use of high energy consuming feedstuff.

Carefully designed, timed and intensively managed cover cropping and rotations are commonly an integral part of weed, pest, and disease management strategies in OA systems. When planted between annual crop cover crops can help restore soil fertility, increase biomass and reduce soil compaction and erosion. They also contribute to moisture retention, weed control, and it they are flowering, are useful for pest management by creating habitat for beneficial insects. In orchard and vineyard systems, cover crops enhance biological diversity and aid in pest regulation.

Weeds can be the most important factor in yield loss in some OA systems. The most commonly weed management techniques used in OA production are mechanical cultivation, hand or hand implement, crop rotations, and cover crops. In row crop systems, most growers try to "bring up" weeds by pre-irrigation so they can be cut mechanically before any planting takes place. In general, orchardists also use mechanical controls, especially in the areas where ground covers do not naturally shade out weeds. Drip irrigation and mulches also reduce unwanted weediness, and are considered water conservation technologies as well. Although weeder geese and chickens are effectively used for both weed control and field clean up, this sort of control is employed only on very unusually diversified farms.

1. Introduction

3.6 Agronomic and Ecological Performance during Transition to Organic Management