2. Principles for Conserving Agricultural Ecosystem Services

Agricultural systems have the potential to improve the environment, to be the custodians of critical aspects of farm genetic diversity needed for future agricultural improvement programs around the world, and to host vast populations of wild biodiversity. Yet our production systems have not been developed to do so, in recent history. While modern agriculture has brought vast increases in productivity to the world's farming systems, it is widely recognised that much of this may have come at the price of sustainability. The bountiful yields of modern agriculture have been "purchased" with high levels of nonrenewable and often toxic inputs such as fossil fuels, inorganic fertilisers, pesticides and herbicides. In developing countries, these inputs are often imported and strain the importing country's balance of payments. Often, purchased inputs are used primarily on export crops, and do not improve local food security.

How does this relate to biodiversity? We know that conventional agricultural practices displace nature. Instead of letting the ecosystem control itself, control comes from outside. Industrially-produced fertiliser substitutes for relationships between plants and nitrogen-fixing bacteria, overriding rather than working with agroecosystems. Pesticides and insecticides replace equilibrating mechanisms such as pest and insect predators. But it is equally possible to reverse this approach, to find the ways and means to restore and build on the resilience and strength of the agroecosystem in the struggle to fight pests, diseases or soil deficiencies, or to augment crop yields through pollination. The component of agrobiodiversity which we call "agricultural ecosystem services" is a potent tool to be encouraged and fostered. Agrobiodiversity can be used to reestablish natural balances in farming systems with healthier environments, a more rational use of resources, and a greater dependence on internal rather than purchased controls. And to do this, the primary technique is "biodiversification" of agroecosystems, to evoke self-regulation and sustainability.

Key prinicples for the conservation of agricultural ecosystem services are:

2.1 It is important that everyone- farmers and policymakers both- understand the concept that agricultural ecosystem services can sustain themselves with proper design.

2.2 Ecosystem services have the potential to reduce both off-site inputs and on- and off-site pollution.

2.3 Promoting identification and taxonomy is necessary.

2.4 Assessment of risks over time, relative dependence, and sustainable livelihoods are critical issues for agricultural biodiversity, and need to be in appropriate balance.

2.5. Policy makers are biased toward large scale plans, whereas much of agrobiodiversity is fine-scaled.

2.6 Costs and benefits of agrobiodiversity goods and services need to be identified.

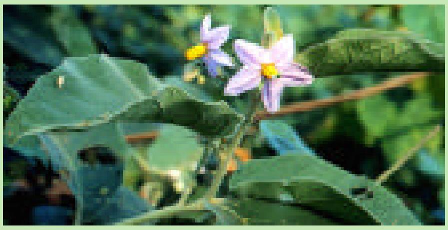
2.7 Costs and benefits need to be distributed on the basis of careful assessment of possible trade-offs, paying attention to incentives and subsidies, and making them appropriate.

2.8 Creating popular awareness and education is necessary for change

2.9 It is necessary to enhance capacity for adaptation to change.

Principle 2.1. It is important that everyone- farmers and policymakers both- understand the concept that agricultural ecosystem services can sustain themselves with proper design.

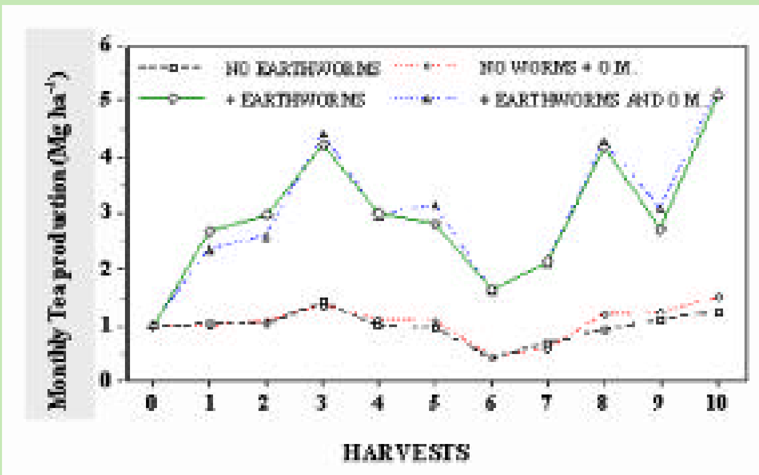
This principle is a key concept behind the notion of ecosystem services, and needs to be understood thoroughly: we often take ecosystem services for granted, as they are provided



Pollination Services in **Kenyan** Horticultural Crops:
In a forested landscape under development for horticultural crops in Kenya, it has been shown that the production of eggplant is entirely dependent on native bee pollinators. Not just any pollinator will do, as eggplant can only be properly pollinated by certain bees which "buzz pollinate" - that is, know how to bite the flower and vibrate their wing muscles at a certain frequency, such that pollen comes flying out of small pores in the flower, and can be carried to another flower to produce fruit. Without this "ecosystem service" , no fruit will be produced. Honeybees cannot buzz pollinate, but it has been shown that two species of solitary bees, which occur naturally in the forest that is being cleared for farms, are very effective pollinators. The bees only get pollen from eggplant, as it does not produce nectar. Thus they cannot live exclusively on agricultural land, and make use of different resources along farm paths, and in the plots of forest that have not yet been cleared. In the dry season, they depend more heavily upon the wild ecosystem for floral resources. Farmers have recognized the importance of this "pollination service" in leaving tracts of forest standing.

from Gemmill and Ochieng 2000

Soil Biodiversity Services in Tea Gardens in **India**:
Long-term exploitation of soil under tea gardens has led to stagnation in yields and quality, as well aswith significant changes in soil physical, chemical and biological conditions including decreasing organic matter content, cation exchange and water-holding capacity. The diversity and abundance of soil biota has also declined. A patented technology entitled "Fertilisation Bio-Organique dans les Plantations Arborées" (FBO) has been developed and tested which improves the physical, chemical and biological soil conditions by inoculating a mixture of low and high quality organic materials (tea prunings and manure) and earthworms into trenches dug between the rows of tea plants. Measurements performed at two sites, beginning in 1994, (see graph) have shown that this technique is much more effective than 100% organic or 100% inorganic fertilisation alone, increasing yields on average by up to 276% and profits by an equal percentage (from around US$2,000 ha^{-1} using conventional techniques to about US$7,600 ha^{-1} in the first year of application. This technique has been extended to other countries and is now being used in over 80 ha. Over 20 million earthworms are being produced each year.



from: http://www.fao.org/landandwater/agll/soilbiod/highligh.htm#macro

Natural Pest Control, Using Biodiversity that Mitigates Pests and Diseases in Maize in **Africa**:

The International Centre of Insect Physiology and Ecology (ICIPE) based in Nairobi, Kenya, is identifying ways to use natural, long-evolved defenses between grasses and their enemies (plant pests) to good use to control stemborers, the major pests of maize in eastern and southern Africa. Losses to stemborers can reach as high as 80% in some areas, and average about 15-40%. Spraying with pesticides is not only expensive and harmful to the environment, but is usually ineffective, as the chemicals cannot reach the pests deep inside the stem. Preventing crop losses from stemborers could increase maize harvests enough to feed an additional 27 million people in the region. Called the "push-pull" strategy, ICIPE'S approach relies on a carefully selected combination of companion crops planted around and among the maize plants. Native and other forage grasses are planted in a border around the maize fields, where invading adult moths become attracted to chemicals emitted by the grasses themselves. Instead of landing on the maize, the insects head for the bordering grasses, forming the "pull" part of the strategy. One of the grasses has its own means of defending itself against the pest, by secreting a sticky substance that traps the insects. The "push" part of the scheme is provided by intercropping plants which repel insects, in the maize field. Fortunately, one plant which repels maize pests, *Desmodium,* is a legume which also enriches the soil and reduces the growth of a parastic weed, *Striga*. Farmers practicing "push-pull" can harvest three crops, maize, *Desmodium* (as animal feed), and forage grasses. Maize production on 150 farms practising "push-pull" in Kenya is up by 25-30% and milk production has increased by an average of 50-60% among participating farmers in Kenya's Suba District, with the benefit-to-cost ratio estimated at 2.25 among farmers using the push-pull approach.

from Khan and Mengech 2001

essentially for "free", so long as we do not abuse the ecosystem. When we lose them, however, we end up paying mightily, for soil fertility amendments, pest control services, and pollination services. It may be helpful to give illustrations of how ecosystem services function, so that we can look at what our policies and plans are ultimately aiming at. Let us consider some illustrations of each of the three main agricultural ecosystem services: pollination, soil biodiversity, and biodiversity that mitigates pests and diseases (see boxes). In addition, we will present below three much-appreviated reviews of the scientific understanding behind each agricultural ecosystem service.

Natural pest control as an ecosystem service:

An estimated 99 percent of potential crop pests are controlled by natural enemies, including many birds, spiders, parasitic wasps and flies, lady bugs, fungi, viral diseases, and numerous other types of organisms (DeBach 1974). These natural biological control agents save farmers billions of dollars annually by protecting crops and reducing the need for chemical control (Naylor and Ehrlich 1997). Scientists have tried to then identify what it is, in an agricultural system, that encourages natural biological control agents. A review of 150 published papers on biodiversity effects on pest occurance (Risch ***et al***. 1983) found that in 53% of the cases plant pest density was decreased in diversified systems, in 18% pest density increased, in 20% a varied response was observed, and no change was observed in 8% of the analysed cases. The mitigating effect of biodiversity appeared to be caused by herbivore response to diversification rather than by enhanced natural enemy activity. While the exact ecological mechanism that determines the effects of agricultural diversification on pests is still not clear, many applied ecologists have turned their attention to plant diversification in their attempt to increase biodiversity and decrease pest impact (Altieri ***et al***, 1991). As stressed in a Swiss strategic planning document, (Anonym, 1989) an increase in plant biodiversity is accompanied by an increase in the biodiversity of other taxa such as arthropods. Moreover, maintaining biodiversity is important because we cannot always identify which species are critical, or which species are important in the future (Burton ***et al***., 1992).

Soil biodiversity as an ecosystem service

Soil organisms play a central role in the decomposition of dead organic matter and wastes, and this decomposition process also renders harmless many potential human pathogens. People generate a tremendous amount of waste, including household garbage, industrial waste, crop and forestry residues, and sewage from their own populations and their billions of domesticated animals. A rough approximation of the amount of dead organic matter and waste (mostly agricultural residues) processed each year is 130 billion metric tons, about 30 percent of which is associated with human activities (derived from Vitousek et al. 1986). Fortunately, there is a wide array of decomposing organisms-ranging from vultures to tiny bacteria-that extract energy from the large, complex organic molecules found in many types of waste. Like assembly-line workers, diverse microbial species process the particular compounds whose chemical bonds they can cleave and pass along to other species the end products of their specialised reactions. Many industrial wastes, including soaps, detergents, pesticides, oil, acids, and paper, are detoxified and decomposed by organisms in natural ecosystems if the concentration of waste does not exceed the system's capacity to transform it.

In agricultural systems, it is important to make efforts to keep a viable component of soil biota, as many of the changes that people impose on soils when they farm are not advantageous to soil organims. It has been well documented, that the conversion of natural vegetation to other land-uses, including agriculture, results in change in the diversity of the soil community. As land conversion and agricultural intensification occur, the ***planned*** biodiversity above-ground is reduced (up to the extreme of monocultures) with the intention of increasing the economic efficiency of the system. This impacts the ***associated*** biodiversity of the ecosystem – micro-organisms and invertebrate animals both above and below ground - lowering the biological capacity of the ecosystem for self-regulation and thence leading to further need for substitution of biological functions with agrochemical and petro-energy inputs. We know that soils change under agriculture, but we do not know the critical point at which biological processes cease to dominate, and purchased inputs must compensate. The detection of critical thresholds for functional change is however still a matter of debate. The high biodiversity within many functional groups has been interpreted as conveying a substantial degree of redundancy to the soil biota and led to suggestions of high resilience (Swift et al., 1996; Lavelle et al., 1997; Giller et al., 1997).

There are a wide range of 'soil bio-technologies' that have the potential to increase and sustain productivity that are currently under-utilised because of the lack of critical evaluation for application to small-scale agriculture. The soil biota may be manipulated by both direct and indirect means. ***Direct*** management includes inoculation with species of soil biota, including nitrogen-fixing bacteria, mycorrhizal fungi, control agents for pest and diseases and beneficial macrofauna such as earthworms. Modern molecular research is also increasing the potential for genetic manipulation of some of these organisms prior to inoculation. ***Indirect*** management is achieved through manipulation of the living plant and cropping system, organic matter of differing resource quality, other soil amendments and soil tillage.

Pollination as an ecosystem service

One third of human food is derived from plants pollinated by wild pollinators. Without natural pollination services, yields of important crops would decline precipitously and many wild plant species would become extinct. In the United States alone, the agricultural value of wild, native pollinators - those sustained by natural habitats adjacent to farmlands - is estimated in the billions of dollars per year. As many agricultural landscapes across Europe and North America have become uniform over vast areas, traditional nesting sites for pollinators on farms, such as hedgerows, field margins and other “waste places” have been eliminated. Pollination services provided to crops under modern agriculture have declined precipitously, and there is a recognised need to conserve these services.

TOOLS

- The definitive volume on ecosystems services is the following book, with chapters on soil, pollinators, and natural pest control, among others:
  Dailey, G. 1997. Nature’s Services: Societal Dependence on Natural Ecosystems. Island Press, Covelo, CA. 392 pp.
- A subsequent review article in Nature is widely cited: Robert Costanza et al., "The Value of the World's Ecosystem Services and Natural Capital," Nature, Vol. 387 (1997), p. 259.

Principle 2.2 Ecosystem services have the potential to reduce both off-site inputs and on and off-site pollution.

In all agroecoystems, the cycles of land, air, water, and wastes have become “open”: meaning farm productivity depends on inputs acquired from off the farm, and produces outputs that are not recycled but need to be disposed of. This is true of all modern agriculture, but it occurs to a larger degree in industrialised commercial monocultures than in diversified small-scall farming systems dependent on human/animal power and local resources. The modern farming systems that are replacing traditional practices around the world and achieving high levels of productivity by “controlling” the environment butthese modern systems require large amounts of imported energy to accomplish the work usually done by ecological processes in less disturbed systems. Agricultural research and development is at a new turning point now, to find ways to reduce the wasteful resource use patterns of modern agriculture, and eliminate its detrimental impact on the environment by harnessing ecological services.

The search for self-sustaining, low-input, diversified and energy-efficient agricultural systems is now a major concern of some researchers, farmers, and policymakers worldwide. Key strategies for low-input sustainable agriculture are primarily achieved through the overall design of the farming system to promote fundamental ecosystem services. From a management viewpoint, the basic components of a sustainable agroecosystem which will enhance these functions include the following:

BEST PRACTICES

Using vegetative cover as an effective soil and water-conserving measure, met through the use of no-till practices, mulch farming, use of legume cover crops, green manures, and so forth.

Returns of farmyard manures and household wastes, with or without composting;

Integrated Soil Fertility Management (ISFM) ie the judicious use of both organic and inorganic sources of nutrients rather than either alone;

Using nutrient recycling mechanisms throught the use of crop rotations, crop/livestock mixed systems, agroforestry and intercropping systems based on legumes, and so forth.

The use of conservation tillage rather than continuous deep ploughing;

Choice of crops and associated plants which have high nutrient use efficiency.

Natural pest regulation enhanced through biodiversity manipulations.

Considering the resource needs of pollinators, on the farm.

Promoting a diversified farm landscape, including crop rotations and intercropping within the fields, but also diversification on the edges and outside of the farm, for example, in crop-field boundaries with windbreaks, shelterbelts, and living fences, which can improve habitat for wildlife and beneficial insects, provide sources of wood, organic matter, resources for pollinating bees, and in addition, modify wind speed and the microclimate.

The basic concepts of a low- external input sustainable and diverse agricultural systems must be synthesised into practical alternative systems to suit the specific needs of farming communities in different agroecological regions of the world.

One way of promoting sustainable agriculture is to simply improve farm management. Well-managed farming systems nearly always use less synthetic chemical pesticides, fertilisers and antibiotics per unit of production than comparable, but less well-managed farms. Reduced use of these inputs lowers production costs and lessens agricultures's potential for adverse environmental and health effects without necessarily decreasing, and in some cases increasing, per-acre crop yields and the productivity of livestock management systems (NRC report on alternative agriculture).

Another approach to sustainable agriculture is to aim for a common standard that incorporates all of the above practices; the most viable of these is the organic farming movement. Organic farming is a production system that sustains agricultural production 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. Whether certified or not, or wholly organic or not, farming systems that aim for the standards of organic farming are learning to depend on ecosystem services. However, it should also be noted that lower-input farming practices of organic agriculture typically require more information, trained labor, time and management skills per unit of production than conventional farming. Thus, extension services and farmer-to-farmer sharing of information is of major importance.

TOOLS

- Farmer-to-farmer exchanges, such as the farmer field schools employed in Indonesia, as described in Roling and van de Fliert (1998), have been very effective in facilitating the sharing of information among farmers. .
  see also documents available for download, at: http://www.communityipm.org/downloads.html
- NGOs have had a large role to play in the spread of alternative agriculture practices. The SANE program aims to enhance capacity building and human resource development in the area of sustainable agriculture through agroecological training,

participatory research, policy advocacy and information networking among no-governmental organisations and other national/international organisations in Africa, Asia and Latin America.
http://nature.berkeley.edu/~agroeco3/sane/index.html

- Sustainable agriculture extension programs; the International Service for National Agricultural Research offers a number of resources for strengthening both research and extension: http://www.cgiar.org/isnar/
- LEISA: There are numerous NGOs and community groups networked through the Dutch-based Centre for Information on Low External Input and Sustainable Agriculture (ILEIA). This organization, founded in 1984, was a response to concern that 'mainstream' agricultural development was by-passing the small farmers of the South. ILEIA started to identify promising technologies involving only marginal external inputs, and building on local knowledge and traditional technologies, involving the farmers themselves in development. It produces the quarterly LEISA Magazine , in which a large number of local initiatives is given publicity. While management of biodiversity is not the primary aim, promotion of biodiverse agriculture is a central part of ILEIA's activities.
http://www.ileia.org; publication of a journal four times a year. Local organisations and individuals in the South can receive this publication free of charge on request. To subscribe, write to ILEIA or send an e-mail to: subscriptions@ileia.nl.
- IFOAM, the International Federation of Organic Agriculture Movements, represents the worldwide movement of organic agriculture and provide a platform for global exchange and cooperation.. IFOAM is committed to a holistic approach in the development of organic farming systems including maintenance of a sustainable environment and respect for the need of humanity. The federation's main function is coordinating the network of the organic movement around the world.
http://www.ifoam.org/

Principle 2.3 Identification and taxonomy is essential for supporting agricultural ecosystem services.

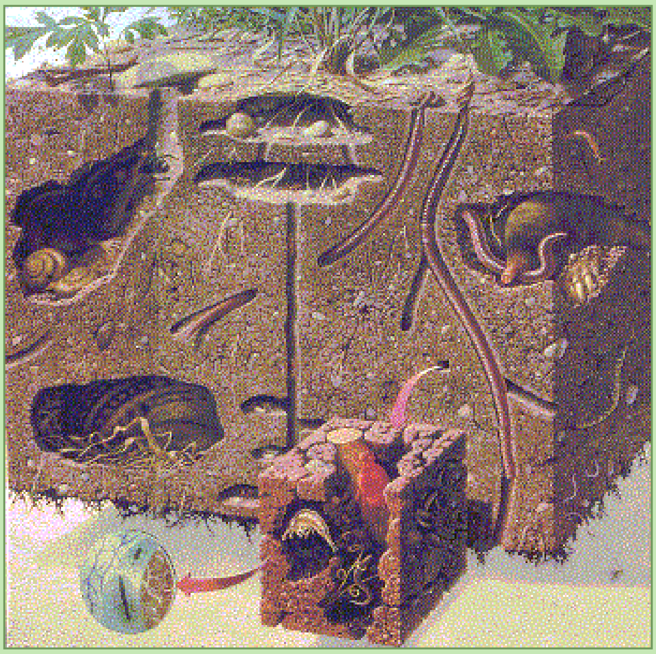
In many areas of biological diversity, there is a need for greater species identification and taxonomy. But nowhere is the need greater than for those organisms involved in agricultural ecosystem services: pollinating insects, soil fauna, and biodiversity involved in pest regulation. These are the "little things that run the world": insects, for example are far more numerous than any other taxa on earth.

Having the correct identification name gives access to correct and relevant information, a wrong name leads to false and irrelevant information. Taxonomy is that branch of science dedicated to discovering, identifying, naming and classifying organisms (species) and understanding their relationships. It provides an information system based on these relationships and is the foundation of all biological science. It allows us to distinguish individual species from amongst the millions with which we share this planet, and to understand their place, role and functions within living systems.

The state of knowledge of smalll organisms, such as insects and microbia that figure so prominently in ecosystem services, is still very rudimentary. Yet taxonomists are themselves an endangered species. For example, the following information has been compiled on the number of practising bee taxonomists associated with major institutions by country or region, as of 1999:

Let us take **soil organisms** as an example, although the same problems and similar solutions may apply to other functional groups. The soil biota constitutes a major fraction of global terrestrial biodiversity. The majority of the terrestrial phyla of invertebrates, protists, fungi and bacteria are represented in the soil community. Within each of these groups the species diversity may also be extremely high. The different groups require different methods for their extraction from soil, identification and quantification. The necessity for using a variety of methods, many of which are destructive to the soil habitat means that there is no single case where a full inventory of the soil diversity has been achieved. For some groups the methods have significant limitations and the percentage recovery of even the highest estimates may be low. This is particularly so for the micro-organisms. Traditional methods relied on the use of agar growth media to isolate fungi and bacteria but it is recognised that this is highly selective and results in only a small fraction of the diversity being recognised. Hawksworth (1999) estimated that less than 1% of fungi were identified with these methods. Molecular methods have given much greater insights. Torsvik et al (1994) demonstrated the existence of 13,000 genetically distinct bacterial types in a small sample of soil compared with only 66 isolated by the conventional plating techniques.

More efficient inventory is possible for the invertebrates, but levels of diversity are still very high. Over 1000 species of invertebrates were identified in 1m2 of soil in temperate forests in Germany (Schaefer and Schauermann, 1990).



from the Soil Biodiversity Portal- see tools

Because of the very demanding nature of soil biota inventories, the practice of using 'Key Functional Groups' has become more common (see Box, below). This approach economises on expertise, time and cost by obviating the necessity of attempting to assess all groups. There is as yet no general agreement on the number of groups to be used or on their definition but three broad criteria can be applied. The first is that of distinct functional identity, ie. that the different groups have distinct and clearly definable functions within the ecosystem. Some of these functions are very specific, such as nitrogen fixation, whilst others are more general, such as soil structure modification. Second the set should embrace a wide range of taxonomic groups. Third the characterisation of the group in terms of identity and abundance should be relatively easy.

One possible list of Key Functional Groups of the soil biota which fulfill these criteria:

Ecosystem Engineers (eg. macrofauna such as termites and earthworms
Microregulators (eg. microfauna such as nematodes)
Micro-symbionts (eg. mycorrhizal fungi, rhizobia)
Soil-borne pests and diseases (eg. fungal pathogens, invertebrate pests)
Carbon and Nutrient transformers (eg. methanogenic and nitrifying bacteria)
Decomposers (eg. cellulose degrading fungi or bacteria)

USA [1]	Mexico	Brazil [2]	Europe[3]	Africa	China	Japan	Australia
10	1	6	3	2	1	2	3

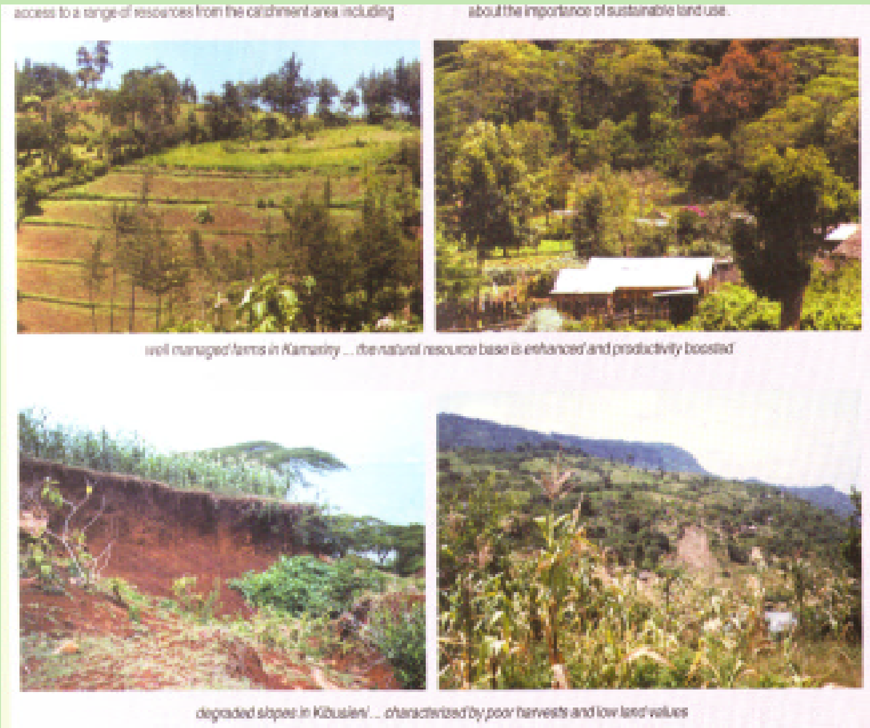
[1] includes 7 workers officially retired, but still active
[2] includes 2 workers officially retired, but still active
[3] includes 1 worker officially retired, but still active
source: Dias, Raw and Imperatri –Fonseca, 1999

As can be seen, young taxonomists are not replacing older and retiring specialists. New techniques are desperately needed to make taxonomomic tools that can be used by non-specialists.

However, there are a number of attempts to make the indentification process which is so critical to soil biota, pollination conservation and natural pest control easier for non-specialists to use (see box, soil organisms). A large intergovernmental initiative, BIONET, has been set up for taxonomic capacity buidling in developing countries, which seeks to link experts and needs around the world, particularly for agriculture- related taxonomic identifications. Ways of training parataxonomists have been explored for pollinating bees; a simplified key to the genera of bees of North and Central America has been developed in English and Spanish (Michener, McGinley and Danforth 1994), and three 10-day sessions of the “Bee Course” have been held in the southwestern US, bringing together an international group of pollination biologists and field scientists with experienced bee taxonomists.

TOOLS

- Soil Biodiversity Portal:
  This website, maintained by UN FAO, provides general conceptions on the meaning and significance of soil biodiversity, stressing the need for integrated biological soil management. It also provides a framework under which soil biodiversity can be assessed, managed and conserved.
  http://www.fao.org/landandwater/agll/soilbiod/default.htm
- BioNET-INTERNATIONAL, the Global Network for Taxonomy, is an inter-governmental initiative for taxonomic capacity building in developing countries. BioNET-INTERNATIONAL is dedicated to supporting regional and national poverty eradication programmes via sustainable use of natural resources, agricultural development, and conservation of biodiversity by enabling developing countries to achieve realistic self-reliance in the skills of identifying and understanding the relationships of the different organisms which constitute our living environment. It is comprised of sub-regional LOOPs (Locally Organised and Operated Partnerships) of developing country institutions, supported by a consortium of developed country institutions (BIOCON), and a Technical Secretariat (TecSec).
  http://www.bionet-intl.org/
- The presence of key groups of natural enemies may be used as indicator when it is not possible to identify every component species. The monitoring of natural enemy effects via antagonist-prey ratios has been proven to be very effective (Nyrop & van der Werf, 1994).
- Information about the Bee Course can be obtained by contacting:
  Dr. J. Rosen, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024-5192, USA
- Michener, C.D., R.J. McGinley and B.N. Danforth. 1994. The Bee Genera of North and Central America (Hymenoptera: Apoidea). Smithsonian Institution Press, Washington, D.C.



In two sub-locations of Keiyo District in **Kenya**, two micro-catchments that are virtually identical in terms of ecology stand in stark contrast - the result of actions taken, or not taken, by local groups. A cost benefit analysis carried out on Kamariny and Kisbusieni micro-catchments found that one group of farmers is reaping the benefits of their investment in soil conservation, while the other is wallowing in all the classic symptoms of land degradation.

Kamariny and Kibusieni are both situated on the escarpment in Keiyo district, with similar soil types, elevation and vulnerability to erosion. Over the years the 28 households of the Kamariny microcatchment (total of 50 acres) have invested heavily in planting treees, building stone walled terraces and planting napier grass to prevent erosion. They spend an equivalent of Ksh 17,000 (more than $200) per household in cash and labour on soil conservation measures. The 45 households in the more densely populated Kibusieni micro catchment spend an average of only Ksh. 1,400 (less than $20) each on soil conservation measures each year.

The benefits to the people in Kamariny are many. They have access to a range of resources from the catchment area including vegetables, honey, medicinal plants, wild fruits and adequate water from the springs. Most of these are no longer available in Kibusieni and households have to source them from further afield. The dividends in terms of farm output are also clear. In Kibusieni, farmers experience poor yields, with a minimum yield 8 times less than in Kamariny. Furthermore the output of maize in Kamariny has been increasing steadily over the years, while it has been on the decline in Kibusieni. The mean worth of an acre of land in Kamariny is about Ksh 75,893 (about $1,000) while in Kibusieni it is only 46,756 (about $625). Thus environmental conservation has a strong positive influence on the land productivity and its value in general.

The study underlines the role of community initiative in bringing about positive changes in community based natural resource management, and that investing in land can yield high dividends. Conversely, it also confirms that external support can do little if local people are not themselves ready for change (both communities received development support in the past). Such experiences will be crucial in raising awareness among local communities about the importance of sustainable land use.

from SARDEP 1999-2001 MidTerm Progress Report

Principle 2.4 Appreciate that while policy makers are biased toward large – scale plans, much of agrobiodiversity is fine-scaled.

As we seek to develop more ecologically-based agricultural development programmes, new understandings and capacities will need to be built among agricultural policy makers, the agricultural research community, and farmers. Modern agricultural research has sought to find technological packages that can be applied across a wide range of heterogeneous agricultural environments and circumstances, usually by making the environment more uniform, with irrigation and agricultural inputs. The challenge now is to find more site-specific ways of managing agricultural lands. Cropping systems and techniques tailored to specific agroecosystems result in a more fine-grained agriculture, based on appropriate traditional and improved genetic varieties and local input and techniques, with each combination fitting a particular ecological, social and economic niche. The participation of farmers, who have this intimate knowledge of the lands they manage, becomes of even greater importance (see box, left).

For the key functional groups providing agricultural ecosystem services (pollinators, soil biota, natural enemies of agricultural pests) we do know of a number of best practices for promoting their persistence in an agricultural landscape. How to translate this into agricultural policy will need the concerted attention of national agricultural planners and policy makers, in dialogue with biodiversity planners.

We know that following the set of best practices below will promote the ecosystem services to be provided by pollinators, nutrient recyclers, and natural enemies of crop pests. Few farmers will have the time or resources to address each "Best Practice" in turn, but many of them are subsumed under general land conservation activities. With a small investment in further public education, farmers who are already inclined toward good land stewardship may learn to watch out for the small resource areas or special considerations that beneficial farm biota require. With more emphasis on farmers' learning structures (section 3.5), farmers can learn from each other.

BEST PRACTICES

- Promote diverse landscapes and spatial differentiation
- Leave wild strips
- Reduce applications of pesticides
- Conserve resources for pollinators
- Exploit areas differently or rotate.
- Use additives that enrich the soil further
- Use less machinery
- Reintroduce/inoculate soil beneficial organisms
- Recycle organic waste
- Promote habitats on-farm that reduce pests and increase natural enemies
- Practice soil conservation measures

Diversity of land use can be attained by a variety of methods. They include crop rotations, adapting choice of crops and cultural methods to soil and soil moisture conditions, interplanting crops in a mixture (polyculture), or planting crops among useful trees either conserved in land preparation or deliberately planted (agroforestry). There are also various mixed farming systems in which arable, trees and livestock are integrated. The values of maintaining landscape level diversity in any of these ways include maximizing the use of land, managing pests and diseases, sustaining habitats for pollinators and other useful biota, and enhancing biodiversity in the soil, as well as sustaining both floral and faunal diversity. It should be kept in mind that it is much more common to adopt different management methods on different micro-environments on small farms. Land tenure issues and policies to promote this kind of site-specific management are discussed in section 3.3.

Principle 2.5 Assessment of risks over time and relative dependence are critical issues for both national agricultural policy and biodiversity strategies.

The objectives of ecosystem management are the optimisation of sustainability, the minimisation of risks and the maximisation of ecosystem services. National planners must carefully address the issue of minimising risks, for the sustainable livelihoods of their citizens. In relation to agriculture, many of the inherent risks relate to decisions on appropriate agricultural yields, and how to obtain those yields. A national agricultural policy on sustainable agriculture includes, whether implicitly or explicitly, the yield expectations of the country; a farmer's approach to production also includes a yield expectation. If it is expected that yields must be high, a high level of risk must be expected. Other systems tolerate lower yields and lower risks. This is a matter of societal choice, as well as ecological factors.

One aspect of high risks is a heavy dependence on outside sources of material or technology. A transition to more sustainable agriculture has added benefits, in terms of minimising risks, in that the farming system becomes more "closed", using internal inputs and ecosystem services rather than outside, purchased inputs.

The model of Cuba, as it made a rapid nationwide conversion to organic agriculture, is a

Since **Cuba**'s trade relations with the Eastern bloc fell in 1990, pesticide imports dropped by more than 60%, fertilizers by 77%, and petroleum for agriculture dropped by 50%. Suddenly, an agricultural system almost as modern and industrialized as that of California was faced with a tremendous challenge: the need to double food production and reduce inputs by half and at the same time maintain export crop production so as not to further erode the country's desperate foreign exchange position.

Since 1989, the Cuban government has adopted a policy to promote a new science of agriculture more in tune with the scarce resources and the need for food self-sufficiency. Cuba's new research directions heavily emphasise understanding and exploiting the subtle yet powerful abilities of biological organisms to perform many of the tasks previously done by synthetic chemicals. Biologically based or derived fertilisers and biological control of pests are at the heart of this new quest for biologically sophisticated management of agroecosystems.

The policy objectives during this special period, to achieve a low petro-chemical input sustainable agriculture without reducing yields, have required a major reorganisation in the structure of agricultural research and extension in Cuba and the flow of information. The de-emphasis of capital- and energy-intensive technologies requires new relationships between scientists, extension agents, and farmers. The pre-existing role of scientists as generators of innovative technological packages and of extension agents as conduits of their delivery to farmers is clearly changing in favor of a new partnership between the three in the development and dissemination of new agricultural approaches.

good object lesson not only in the efforts needed, but also the benefits possible by such a transition. (see box).

Principle 2.6 Costs and benefits of agrobiodiversity goods and services need to be identified and distributed on the basis of careful assessment of possible trade-offs, paying attention to incentives and subsidies, and making them appropriate.

We do not yet have a well-developed analysis of the costs and benefits of ecosystem services. Some review articles and widely cited texts have given very impressive figures for the valuation of ecosystem services, yet few of these values are yet reflected in conventional economic accounting systems. To get these services properly entered into national economic accounting, we need to have highly realistic, well documented analyses of costs and benefits.

Cuban scientists have become increasingly reliant on farmer innovation and experimentation for research directions that complement their efforts to develop promising organic farming practices as well as to adapt techniques developed outside the country. They are emphasizing technologies recovered or developed at the local

level that have widespread applicability, which extension agents and scientists disseminate over a broader region, and low-input technologies utilized in other countries, which are promoted for local experimentation and adoption.

One of the keys to Cuba's new model of agriculture is to find ways to reduce chemical use fo management of plant disease, insect pests, and weeds. The most interesting aspect of contemporary insect pest management efforts in Cuba are the Centers for the Production of Entomophages and Entomopathogens (CREEs) where decentalised, "artesanal" production of biocontrol agents take place. Despite limited resources, the government has invested its capital in construction and operation of these centers. By the end of 1992, 218 CREEs had been built throughout Cuba to provide services to state, cooperative and private farmers.

The centers produce a number of entomopathogens (*Bacillus thuringiensis, Beauvaria bassiana, Metarhizium anisopliae,* and *Verticillium lecani*), as well as one or more species of Trichogramma, depending on the crops grown in each area. CREEs are maintained and operated by local technicians.
Cuban scientists are also pursuing several other lines of research in developing alternatives to conventional insecticides, including work on parasitic nematodes and plant-derived pesticides. A program to develop reliable and cost-effective methods for the production and field application of several species of nematodes that attack insects is currently under way; however, mass production is still in the developmental stages.

Scientists are also screening a large number of plants for insecticidal, fungicidal, bactericidal and herbicidal qualities. In addition to these screening effors, applied work has been initiated on the cultivation and production of two species of plants with known insecticidal qualities, neem and Melia. Small plantations of neem and Melia have been started and research on formulations and application methods is advancing.

from Altieri

Examples of negative side effects of pesticide use

* estimated 1 million pesticide poisoning cases per year
* ca. 20,000 deaths per year
* chronic health effects
* pollution of drinking water
* pesticide residues in food
* damage to beneficial insects and the natural environment
* lack of sustainability in agricultural production

Policy factors which may contribute to excessive use of pesticides:

Price Factors

Government sells pesticides below market price or distributes them free of charge

Donors provide pesticides at low or no costs

Government subsidises pesticide companies

Subsidized credit for pesticide use

Preferential rates for import duties, taxes and exchange rates

Plant protection service outbreak budget

Non Price Factors

Misguided use of governments' activities in reducing pesticide damage
Governments' investment in pesticide research

Inadequate government research in environmentally benign pest management

Lack of adequate procedures for pest and crop loss definition

Lack of information on non-chemical measures

Lack of transparency in regulatory decision making

Lack of internalization of pesticide production and use externalities

source: GTZ Pesticide Policy Project

Thus, the essential BEST PRACTICES with respect to each agricultural ecosystem service, are:

Pollinators

Assess the economic contribution to yield/opportunity cost of altering habitat.
Assess the economic contribution of pollinators to conserving the genetic diversity of crops.
Review the system of economic instruments that affects the distribution of costs and benefits of pollination services.
Create a market for pollination services based on ecosystem management principles.

Soil Bio-Diversity

- Assess the economic contribution of soil biodiversity at various scales with linkage to potential funding mechanisms at watershed, national and global scales.
- Assess the benefits and costs of integrated soil management versus conventional practices at farm and watershed level.
- Review the system of economic instruments that affects the distribution of costs and benefits of pollination services.
- Develop support for organic and biodiversity-friendly farming by small holders.
- Assess the new market for greenhouse gases (CH_4, CO_2, NO_x, SO_2), mitigation, water quality enhancement, etc. provided through soil biodiversity conservation.

Pests

- Assess the benefits and costs of mitigation strategies involving crop management practices, habitat boundaries and IPM.
- Develop support for organic and biodiversity-friendly farming by small holders.

Even in the absence of detailed valuations of agricultural ecosystem services, there are many initivatives underway to develop markets for organic agriculture, which includes the promotion of most agricultural ecosystem services. GTZ, for example, supports several programmes that seek to build such markets. One of the these, Protrade, encourages public-private-partnerships. Specialising in trade and business promotion, the program offers assistance in sector-related marketing, product and production consulting in more than 90 countries, promotion in Germany and the EU, trade fair assistance and a comprehensive information service. Protrade included an organic products sector in 1993 in reaction to the growing demand for biological cultivation of products and the strong interest of many third world countries in organic agriculture and farming (Thies 2000). The main emphasis of the work in the organic products sector is on developing new trade contacts, consulting in the areas of organic farming, certification, product development, management and quality assurance, as well as offering support for participation and international specialist trade fairs. Fifteen countries are currently in the consulting programme: the Dominican Republic, Ecuador, Haiti, Honduras, Kenya, Madagascar, Mexico, Nicaragua, Peru, Russia, Senegal, Zimbabwe, Uruguay and Tanzania.

One key element of building markets, and assuring that farmers receive sufficient incentives for conserving agricultural biodiversity, is to develop certification systems that guarantee organic products for consumers, and higher prices for producers. TransFair is a seal offered by the labeling initiative “Transfair International” to traders who buy from registered cooperatives in developing countries and abide by fair trade criteria. Products covered by the TransFair seal include coffee, honey, cocoa, sugar and tea. Several other initiatives like TransFair are all grouped in the Fair Trade Federation. They, and other important actors in the field of labeling organic products can be found on the websites given in Tools, below.

Along with building proper incentive measures, it is important to eliminate pervese subsidies, of which there are many in the agriculture sector. There is a growing recognition that currently most if not all policy measures used to support agriculture act as powerful disincentives against sustainable agriculture, especially with respect to subsidies for agricultural inputs. Countries have adopted these policies because they believe that the economic benefits outweigh public expenditure. But in fact, recent research shows that the use of chemical pesticides has been promoted and subsidised by governments even though there has been little information on the net benefits of a dependency on pesticide usage compared to other crop protection strategies (GTZ Pesticide Policy Project, no date). AGENDA 21 of the United Nations Conference on Environment and Development in 1992 demands the implementation of integrated pest management (IPM) as an alternative to dependency on unilateral use of agricultural chemicals. This concept stresses the use of local knowledge and aims at improving the decision making capacity of farmers instead of disseminating fixed packages of external technology.

But the paradigm switch that is indispensable for the dissemination of IPM will not be obtained without a change in the general institutional framework of economic incentives that govern crop protection. In many instances, national governments hesitate to implement the necessary political changes (see box, Policy Factors). They lack adequate concepts for policy analysis in a sub-sector that is dominated by specialists in natural science and toxicology. Agricultural interest groups fear that policy reform measures aimed at a reduction of chemical pesticides will threaten their competitiveness in global agricultural product markets.

The economic justification of pesticide use in world agriculture and horticulture is often doubtful. Negative side effects occur in many instances but are not accounted for as costs (see box, Negative Side Effects of Pesticide Use). For example, farmers do not consider occupational health costs in their decision to use pesticides. The costs of the damage of the natural environment are born by the society as a whole and only perceived in the long run. They are not embodied in the private costs of pesticide application. Therefore, actual pesticide use often exceeds the social optimum.

There are a number of new resources and initiatives being launched to assist countries to better examine existing policy decisions, and undertake a reform of crop protection policy instruments within government, and private sector approaches (see tools).

TOOLS

- Organisations promoting trade and labelling programs to provide more resources to farmers practicing "green agriculture" include:
  http://fairtradefederation.com
  http:// green-trade.de
  http://www.ifoam.com

- The World Organic Commodity Exchange (WOCS, www.wocx.net) represents over 2500 organic products, including textiles, furniture, cosmetics, wine, vegetables, fruits, dog food, baby food, ice cream and water.

- The pilot project 'Reform of Crop Protection Policy as part of an Agri-Environmental Policy Framework' was initiated by the GTZ (German Technical Cooperation) Department for Rural Development. It aims at developing and testing methodologies and instruments for crop protection policy reform.

  The project focuses on developing and testing instruments for economic policy analysis and tools for policy reform, establishing methodologies for evaluating the impacts of knowledge-based technologies in crop protection, and ensuring sustainability through capacity building and regional networks of local experts in policy analysis

- The book "Bugs in the System" is an edited volume of multidisciplinary approaches to find constructive options for a "redesign" of the pesticide industry.

  Vorley, W. and D. Keeney, eds. 1998. Bugs in the System: Redesigning the Pesticide Industry for Sustainable Agriculture. Earthscan Publications, London.

USA: Change may bring new economic opportunties- the case of poultry manure:

Meat poultry farms in the USA range in size from over 500 hectare to less than 2 hectares. The size of the farm is often not related to the number of chickens grown and therefore the manure produced may be a credit for the farmer because of its fertilizer value or a debit for the cost of disposal. An industry of clean-out companies has developed to service those farms where manure is a disposal problem. Clean-out companies remove the manure for a fee and then sell the manure to other farmers.

Because the concentration of manure around feedlots has become a severe problem, state governments have begun to legislate mandatory nutrient management programs to protect the environment. For instance those farmers with excess nutrient must adopt transport or treatment measures to prevent excess application of N and P on their land. State funded programs pay farmers a transport fee to move manure to farms that can utilize it effectively. Assistance can also be obtained for the development of new or improved treatment technologies by research institutions and private enterprise.

Principle 2.7 It is necessary to enhance capacity for adaptation to change.

If we are to make sweeping changes in the way our food is produced, and institute a greater reliance on ecosystem services, it should be recognised that under any “change management” there are transaction costs.

The process of conversion from a high-input conventional management to a low-input (or low-external input) management is a transitional process which can have considerable costs for farmers. There are four identified phases in making this transition :

1. Input withdrawal: progressive chemical withdrawal.
2. Efficient input use: rationalisation of agrochemical use through integrated pest management (IPM) and integrated nutrient management.
3. Input substitution: using alternative, low-energy inputs
4. System redesign: redesign of diversified farming systems with an optimal crop/ animal assemblage which encourages synergies so the the system can sponsor its own fertility, natural pest regulation and crop productivity.

During the four phases, management should be guided in order to ensure the following processes:

1. Increasing biodiversity both in the soil and above ground
2. Increasing biomass production and soil organic matter content.
3. Decreasing levels of pesticide residues and nutrient and water loss.
4. Establishment of functional relationships between the various farm components.
5. Optimal planning of crop sequences and combinations and efficient use of locally available resources.

As well, there are a number of constraints that the “change management” regime must contend with. First labor inputs are substantially greater for organic technology than for conventional production; productivity may average 22 percent to 95 percent less than under

An organic agriculture design for the **Peruvian Sierra**

An agricultural NGO implemented an organic agriculture proposal for the region, with basic aspects as:

- rational use of local resources, potentiation of natural resources, and intensive use of human and animal labour.
- High diversity of native (Andean) and exotic crops, herbs, shrubs, trees and animals grown in polycultural and rotational pattersn
- Creation of favorable microclimates through the use of shelterbelts, and living fences and reforestation with native and exotic fruit and trees.
- Recycling of organic residues and optimal management of small animals.

from Altieri 1997

conventional production.

Another constraint is adequate quantitites of organic fertilizer like manure. As livestock production is becoming more and more concentrated in feedlots, whole regions are finding that a shortage of manure on farm is complemented by toxic concentrations of animal waste on feedlots, often near urban areas. This poses the potential for developing sound regional ecosystem interdependencies, but the systems to share such resources in a rational manner need to be developed (see xxx).

Capacity is another large constraint for organic farmers. A study by Blobaum (1983) of farmers in the United States noted that several capacity- and information- related obstacles discourage conventional farmers from adopting organic methods. Organic farmers perceive the lack of access to reliable organic farming information as a serious barrier to conversion. Most rely primarily on information from other organic farmers and from such nontraditional sources as books and magazines, representatitves of organic fertilizer companies, and workshops and conferences. Organic farmers have a strong interest in research on many problems, and most farmers would adopt new practices if more research-substantiated information were available.

Blobaum also found that organic farmers who use special markets are dissatisfied with problems such as small orders, long delays in getting paid, inadequate returns for cleaning and bagging grains, confusing certification standards, difficulty in contacting buyers, and the expense of maintaining special on-farm storage areas.

Credit discrimination is seen as a potential problem by a sizeable number of organic farmers. The long-term economic benefits of organic agriculture may not be evident to a farmer faced with having to make payments on annual production loans. Many conventional farmers are greatly in debt, and their debt constrains the shift to more sustainable methods.

Encouragingly, recent economic evaluations suggest that profits from organic farms can exceed those of conventional farms. Eventually, farmers should be able to reap economic benefits from practising a more sustainable production system. But farmers' inability to overcome the multiple constraints, as listed above, may impede the transition to more sustainable agriculture. The costs of making the transition should not, and cannot, be borne by farmers alone. Governments and non-governmental organisation should seek ways of helping the agriculture sector adapt to changes in ways that benefit all of society.

Governments should appreciate that changes need to be phased and strategically designed. In the case of Denmark, which aims to become a pesticide-free country within five years, considerable work has gone into developing a phased, methodical transition to alternative technologies. The research and logistical development which will be necessary to support this transition come from investment on the part of the Danish government.

Non-governmental organisations can also play important roles in making transitions, particularly when they assist in developing "redesign strategies" (see box). Altieri fournd that in Latin America, NGOs working with communities and applying agroecological methods have shown that transitions to organic production need not be the perogative of developed countries, or naturally productive areas. Even within a policy environment that has not been conducive to sustainable agriculture with a strong political primacy of urban social groups, heavy dependence on industrial production, the absence of effective land distributions, subsidies for fossil-fuel based agricultural inputs, and the limited access of peasants to policital and economic resources, NGOs working with farmer groups have been able to show that low-external input practices can be economically, socially, culturally, and ecologically appropriate for those farmers who have not benefited from conventional agriculture, or farm in marginal areas.

Principle 2.8 Creating popular awareness and education is necessary for change

Ecosystem services may be important, but few people know about them or understand them. Messages on ecosystem services are needed, adhering to the following best practices:

BEST PRACTICES

- Messages on ecosystem services must be simple
- Messsages must target both the public and policy makers
- Information should be packaged for diverse target groups.
- Communicating appropriate knowledge to policy makers is key to appropriate policy formulation.

An initial but by no means comprehensive list of messages which need to be conveyed to the public and to policy makers includes the following:

1. Agriculture depends on the wider environment.
2. Agriculture derives more from environment than technology can substitute.
3. Sustainable agriculture benefits from biodiversity, such as water quality improvement and pollution reduction.
4. Biodiversity benefits can feed back into increased agriculture production, e,g., pollination, or natural pest control can contribute to yield increases.
5. Conversely, loss of pollinators can lead less production and economic benefits
6. These benefits can be quantified.
7. Agricultural practices that maintain soil organic matter also maintain soil diversity.
8. Sustainable economic development is dependent on agrobiodiversity.

A number of creative means need to be undertaken to convey these messages to the public. In the case of the pollination research carried out in Kenya (see box on page 32), research findings were given back to the community and the general public in the form of a colourful poster, distributed through a popular journal. Other innovative public education programmes in relation to soil biodiversity have been started in Australia and Canada (see box).

Public awareness programmes addressing ecosystem services will need to draw on the resources of scientists, and help scientists to work together and with other stakeholders. The Brazilian Government Proposal to the Convention on Biolgical Diversity Subsidieary Body on Scientific and Technological Advice identified institutional and educational factors as the main constraints to effective use of soil biodiviersity (Perez Canhos et al., 1998). These included: low institutional capacity, lack of integration between different groups working on the topics, insufficient information exchange, and lack of public education to appreciate the value of the soil biodiversity. The following goals and strategies were proposed in alleviation:

1. Establishment of a network of laboratories, scientific collections and technical centres.
2. Programmes for education of specialists (Post-graduate programmes in the country and abroad and short courses in the country)
3. Definition of standard sampling protocols

Innovative Programmes of Public Involvement in **Canada** and **Australia**:

Worm Watch is a programme initiated by the Canadian government to promote awareness of the diversity of "life beneath our feet" through public participation in a nationwide earthworm census. The census takers will be students, farmers, producer groups, conservation and naturalist groups, gardeners and interested individuals and families. They will be supplied with a Worm Watch kit containing background material on earthworm ecology and taxonomy, instructions on how to sample and record their data, data sheets, a photographic key showing the most commonly encountered earthworm species, vials for the preservation of earthworms that could not be identified, and a list of references, including a wormwatch website and a toll-free number. An instructional video demonstrating the various sampling techniques should also be available. Scientists will make use of the data collected to inventory and study the distribution of earthworm species in Canada, including correlations between landuse patterns (including undisturbed vs. disturbed habitats, cropping systems, and tillage practices) ecozones, and earthworm populations and species diversity. The data collected should significantly increase the scientific community's understanding of the biogeography of post glaciation earthworm populations, and the history of their distribution. It can also be used to evaluate the potential of using earthworms as one of a suite of bioindicators of environmentally sustainable land use practices, and the information on species diversity and preferred habitat will beuseful when considering policies on introducing earthworms for waste management, integrated pest management, soil improvement, and site reclamation.

Canada's WormWatch program is modeled on an Australian program, the Earthworms Downunder, run by CSIRO, the Australian Department of Eduction and the Double Helix Science Club. This programme used Double Helix science club members to collect and determine the diversity and distribution of earthworm species in Australia. The programme was very successful, and accomplished within one year what would be expected of a team of scientists in five years.

from Clapperton, J. no date.

4. Definition of indicators of soil quality
5. Develop models to measure the economic value of the biodiversity of microorganisms and creation of fiscal incentives.
6. Establishment of specialised discussion groups of researchers
7. Establish thematic networks on soil and micro-organisms biodiversity.
8. Education targeting the appreciation of the value of the biodiversity of micro-organisms and their sustainable use and development.

These actions could act as a model for other countries.