PROSPECTS FOR AGROECOLOGICALLY BASED NATURAL-RESOURCE MANAGEMENT FOR LOW-INCOME FARMERS IN THE 21ST CENTURY

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The Problem and the Challenges.

Despite good global agricultural performance with respect to yield in the last two decades, the numbers of people undernourished only fell by 80 million, from 920 million to 840 million between the late 1960s and the early 1990s. In the last 30 years enough food was produced to feed everyone had it been more evenly distributed. Most analysts agree that poverty is the key reason why 840 million people do not have enough to eat and that at present, hunger is not a matter of agricultural limits but a problem of masses of people not having access to food or the means to produce it.

About 73 million people will be added to the world's population every year from now until 2020 and thus it is possible that food production will not keep pace with demand, implying that food insecurity and hunger will persist as key challenges for the international agricultural research community. But realistically, if the root causes of hunger, poverty and unequal land distribution are not addressed, hunger will persist no matter what agricultural technologies are used. Most modern agricultural technologies have the potential to deal with the issue of quality and quantity of food (which is part of the problem) but does not address the distributive and access aspects of food which are at the heart of the hunger problem. Insisting only on technological solutions to hunger ignore the tremendous complexity of the problem of food scarcity.

Despite the above, few doubt that a huge increase in food production will have to be accomplished sooner or later. Whether the target date will be 2030 or 2050 is a less important question than is how to meet this immense challenge of doubling world food supply? It is not so clear, however, what needs to be done from this point forward to achieve food security for all in the years ahead. Over the past decade, yield increases from the Green Revolution technologies have been decelerating, and in some cases stagnating (Pingali et al. 1995). The highest yields have been obtained by using ever-larger inputs of fertilizer and irrigation water, which in many places have passed the point of diminishing returns. Greater use of these inputs is thus becoming less productive. Moreover, at high input levels, adverse environmental impacts associated with monocultures and agrochemicals are becoming a serious concern.

Soil erosion and degradation, chemical pollution, along with the exhaustion and pollution of surface and underground water sources, deforestation and the destruction of biodiversity in general, are some of the most notorious impacts of the conventional agricultural model. The difficulty in quantifying and assigning monetary values to ecological degradation has not allowed scientists to quantitatively and convincingly prove the hidden costs behind the gains in yields in conventional farming. The model's current production costs have grown alarmingly, even if such externalities are disregarded. Modern agricultural system's energy matrix reveals a tremendous dependency on fossil fuel, as costs rise exponentially with each successive oil crisis. Over the coming 50 years we will obviously be approaching the limits of this approach, unless its energy matrix is changed.

Moreover, for the most part resources-poor farmers of Latin America, Asia, and Africa gained very little from the processes of development and technology transfer of the Green Revolution. Many analysts of the Green Revolution have pointed out that the new technologies were not scale-neutral. The farmers with the larger and better-endowed lands gained the most, whereas farmers with fewer resources often lost, and income disparities were often accentuated. Not only were technologies inappropriate for poor farmers, but peasants were excluded from access to credit, information, technical support and other services that would have helped them use and adapt these new inputs. Although subsequent studies have shown spread of high-yielding varieties among small farmers in some areas, disparities remain.

Areas characterized by peasant agriculture remain poorly served by the transfer-of-technology approach. Due to market and institutional biases in favor of an export oriented agriculture, campesinos have been pushed off the land, further reducing grain production for local and regional consumption and aggravating the cycle between poverty and environmental degradation. By the end of the XX century we can therefore conclude that the modernization of agriculture has not solved the problem of overall rural poverty nor has it improved the distribution of land which remains concentrated. The historical challenge of the international agricultural community is to assume responsibility for the welfare of the small farmers that on average account for 70% of the farms in Latin America and make up 65% of the poor. These farmers occupy fragile environments, but nevertheless are stewards of agrobiodiversity and make a substantial contribution to regional food self-sufficiency. Such resource-poor farmers and their complex systems pose special research challenges and demand appropriate technologies. Such farmers will not likely be the target of the private sector or advanced research institutions.

One thing that is clear to most analysts is that food production will have to come from agricultural systems located in countries where the additional people will live in.

In these countries, farmers are not only resource poor with no access to credit, technical assistance or markets, but their farming systems are complex and diversified with mixes of annual crops, trees and livestock. Many of them (about 370 million rural poor) are located in arid or semi-arid zones or in steep hill-slope areas that are ecologically vulnerable. Thus it is clear that in order to benefit the poor more directly, an NRM approach must be applicable under the highly heterogeneous and diverse conditions in which smallholders live, it must be environmentally sustainable and based on the use of local and indigenous resources. The emphasis must be on improving whole farming systems at the field or watershed level rather than specific commodities. Technological generation must be demand driven which means that research priorities must be based on the socio-economic and environmental needs and circumstances of resource-poor farmers.

The Challenges of a Pro-Poor Natural Resources Management (NRM) Strategy.

Perhaps the most significant realization at the end of the XX century is the fact that areas characterized by traditional agriculture remain poorly served by the transfer-of-technology approach, due to its bias in favor if modern scientific knowledge and its neglect of local participation and traditional knowledge (Lappe et al. 1998). The historical challenge of the international agricultural community is therefore to refocus its efforts on marginalized farmers and their agroecosystems and assume responsibility for the welfare of their agriculture.

The urgent need to combat rural poverty and to conserve and regenerate the deteriorated resource base of small farms requires an active search for new kinds of agricultural research and resource management strategies. NGOs have long argued that a sustainable agricultural development strategy that is environmentally enhancing must be based on agroecological principles and on a more participatory approach for technology development and dissemination (Altieri et al. 1998). Focused attention to the linkages between agriculture and natural resource management will help greatly in solving the problems of poverty, food insecurity, and environmental degradation.

To be of benefit to the rural poor, agricultural research and development should operate on the basis of a "bottom-up" approach, using and building upon the resources already available: local people, their knowledge and their autochthonous natural resources. It must also seriously take into consideration, through participatory approaches, the needs, aspirations and circumstances of smallholders (Richards 1995). This means that from the standpoint of poor farmers, innovations must be:

- Input saving and cost reducing
- Risk reducing
- Expanding toward marginal-fragile lands
- Congruent with peasant farming systems
- Nutrition, health and environment improving

Although statistics on the number and location of resource-poor farmers vary considerably, it is estimated that about 1.9 to 2.2 billion people remain directly or indirectly untouched by modern agricultural technology. In Latin America, the rural population is projected to remain stable at 125 million until the year 2000, but over 61% of this population is poor and is expected to increase. The projections for Africa are even more dramatic. The majority of the rural poor (about 370 million of the poorest) live in areas that are resource-poor, highly heterogeneous and risk prone. Their agricultural systems are small scale, complex and diverse. The worst poverty is often located in arid or semi-arid zones, and in mountains and hills that are ecologically vulnerable (Conway, 1997). These areas are remote from services and roads and agricultural productivity is often low on a crop by crop bases, although total farm output can be significant. Such resource-poor farmers and their complex systems pose special research challenges and demand appropriate technologies that are:

- Based on indigenous knowledge or rationale
- Economically viable, accessible and based on local resources
- Environmentally sound, socially and culturally sensitive
- Risk averse, adapted to farmer circumstances
- Enhance total farm productivity and stability

Many agroecologists have argued that the starting point in the development of new pro-poor agricultural development approaches are the very systems that traditional farmers have developed and/or inherited. Such complex farming systems, adapted to the local conditions, have helped small farmers to sustainably manage harsh environments and to meet their subsistence needs, without depending on mechanization, chemical fertilizers, pesticides or other technologies of modern agricultural science (Denevan, 1995). The persistence of millions of hectares under traditional agriculture in the from of raised fields, terraces, polycultures, agroforestry systems, etc., document a successful indigenous agricultural strategy and comprises a tribute to the "creativity" of small farms throughout the developing world (Wilken, 1997). These microcosms of traditional agriculture offer promising models for other areas as they promote biodiversity, thrive without agrochemicals, and sustain year-round yields.

<u>Agroecology as a fundamental scientific bases for NRM.</u>

For years several NGOs in the developing world have been promoting agroecologically-based NRM approaches. Such organizations argue that a sustainable agricultural development strategy that is environmentally enhancing must be based on agroecological principles and on a more participatory approach for technology development and dissemination. Agroecology provides a methodological framework for understanding the nature of farming systems and the principles by which they function. It is the science that provides ecological principles for the design and management of sustainable and resource-conserving agricultural systems-offering several advantages for the development of farmer-friendly technologies. Agroecology relies on indigenous farming knowledge and selected modern technologies to manage diversity, incorporate biological principles and resources into farming systems, and intensify production. Thus it provides for an environmentally sound and affordable way for smallholders to intensify production in marginal areas.

Agroecology goes beyond a one-dimensional view of agroecosystems – their genetics, agronomy, edaphology, and so on, - to embrace an understanding of ecological and social levels of co-evolution, structure and function. Instead of focusing on one particular component of the agroecosystem, agroecology emphasizes the interrelatedness of all agroecosystem components and the complex dynamics of ecological processes (Vandermeer 1995).

Agroecosystems are communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, fibre, fuel and other products for human consumption and processing. Agroecology is the holistic study of agroecosystems, including all environmental and human elements. It focuses on the form, dynamics and functions of their interrelationships and the processes in which they are involved. An area used for agricultural production, e.g. a field, is seen as a complex system in which ecological processes found under natural conditions also occur, e.g. nutrient cycling, predator/prey interactions, competition, symbiosis and successional changes. Implicit in agroecological research is the idea that, by understanding these ecological relationships and processes, agroecosystems can be manipulated to improve production and to produce more sustainably, with fewer external inputs and lower negative environmental or social costs (Altieri 1995).

The design of such systems is based on the application of the following ecological principles (Reinjntjes et al. 1992) (see also Table 1):

1. Enhance recycling of biomass and optimizing nutrient availability and balancing nutrient flow.

2. Securing favorable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity.

3. Minimizing losses due to flows of solar radiation, air and water by way of microclimate management, water harvesting and soil management through increased soil cover.

4. Species and genetic diversification of the agroecosystem in time and space.

5. Enhancement of beneficial biological interactions and synergisms among agrobiodiversity components thus resulting in the promotion of key ecological processes and services.

These principles can be applied by way of various techniques and strategies. Each of these will have different effects on productivity, stability and resilience within the farm system, depending on the local opportunities, resource constraints and, in most cases, on the market. The ultimate goal of agroecological design is to integrate components so that overall biological efficiency is improved, biodiversity is preserved, and the agroecosystem productivity and its self-sustaining capacity is maintained.

Agroecological management must lead management to optimal recycling if nutrients and organic matter turnover, closed energy flows, water and soil conservation and balance pest-natural enemy populations. The strategy exploits the complementarities and synergisms that result from the various combinations of crops, trees and animals in spatial and temporal arrangements (Altieri 1994).

In essence, the optimal behavior of agroecosystems depends on the level of interactions between the various biotic and abiotic components. By assembling a functional biodiversity it is possible to initiate synergisms which subsidize agroecosystem processes by providing ecological services such as the activation of soil biology, the recycling of nutrients, and the enhancement of beneficial arthropods and antagonists, and so on (Altieri and Nicholls 1999). Today there is a diverse selection of practices and technologies available, and which vary in effectiveness as well as in strategic value. Various strategies to restore agricultural diversity in time and space include crop rotations, cover crops, intercropping, crop/livestock mixtures, and so on, which exhibit the following ecological features:

1. *Crop Rotations*. Temporal diversity incorporated into cropping systems, providing crop nutrients and breaking the life cycles of several insect pests, diseases, and weed life cycles (Sumner 1982).

2. *Polycultures*. Complex cropping systems in which two or more crop species are planted within sufficient spatial proximity to result in complementation, thus enhancing yields (Francis 1986, Vandermeer 1989).

3. *Agroforestry Systems*. An agricultural system where trees are grown together with annual crops and/or animals, resulting in enhanced complementary relations between components increasing multiple use of the agroecosystem (Nair 1982).

4. *Cover Crops*. The use of pure or mixed stands of legumes or other annual plant species under fruit trees for the purpose of improving soil fertility, enhancing biological control of pests, and modifying the orchard microclimate (Finch and Sharp 1976).

5. Animal integration in agroecosystems aids in achieving high biomass output and optimal recycling (Pearson and Ison 1987).

All of the above diversified forms of agroecosystems share in common the following features (Altieri and Rosset 1995):

a. Maintain vegetative cover as an effective soil and water conserving measure, met through the use of no- till practices, mulch farming, and use of cover crops and other appropriate methods.

b. Provide a regular supply of organic matter though the addition of organic matter (manure, compost and promotion of soil biotic activity).

c. Enhance nutrient recycling mechanisms though the use of livestock systems based on legumes, etc.

d. Promote pest regulation through enhanced activity of biological control agents achieved by introducing and/or conserving natural enemies and antagonists.

Research on diversified cropping systems underscores the great importance of diversity in an agricultural setting (Francis 1986, Vandermeer 1989, Altieri 1995). Diversity is of value in agroecosystems for a variety of reasons (Altieri 1994, Gliessman 1998).

- As diversity increases, so do opportunities for coexistence and beneficial interactions between species that can enhance agroecosystem sustainability.
- Greater diversity often allows better resource-use efficiency in an agroecosystem. There is better system-level adaptation to habitat heterogeneity, leading to complimentarity in crop species needs, diversification of niches, overlap of species niches, and partitioning of resources.
- Ecosystems in which plant species are intermingled possess an associatonal resistance to herbivores as in diverse systems there is a greater abundance and diversity of natural enemies of pest insects keeping in check the populations of individual herbivore species.
- A diverse crop assemblage can create a diversity of microclimates within the cropping system that can be occupied by a range of noncrop organisms-

including beneficial predators, parasites, pollinators, soil fauna and antagonists – that are of importance for the entire system.

- Diversity in the agricultural landscape can contribute to the conservation of biodiversity in surrounding natural ecosystems.
- Diversity in the soil performs a variety of ecological services such as nutrient recycling and detoxification of noxious chemicals and regulation of plant growth.
- Diversity reduces risk for farmers, especially in marginal areas with more unpredictable environmental conditions. If one crop does not do well, income from others can compensate.

Applying agroecology to improve the productivity of small farming systems.

Since the early 1980s, hundreds of agroecologically-based projects were promoted by NGOs throughout the developing world which incorporate elements of both traditional knowledge and modern agricultural science, featuring resource-conserving yet highly productive systems, such as polycultures, agroforestry, and the integration of crops and livestock, etc. Such alternative approaches can be described as low-input technologies (e.g., Sanchez and Benites 1987), but this designation refers to the *external* inputs required. The amount of labor, skills, and management that are required as inputs to make land and other factors of production most productive is quite substantial. So rather than focus on what is *not* being utilized, it is better to focus on what is most important to increase food output- labor, knowledge and management.

Agroecological alternative approaches are based on using locally available resources as much as possible, though they do not reject the use of external inputs. Farmers cannot benefit from technologies that are not available, affordable, or appropriate to their conditions. Purchased inputs present special problems and risks for less-secure farmers, particularly where supplies and the credit to facilitate purchases are inadequate.

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 to 100 percent are fairly common with most alternative production methods. 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.

More important than just yields, it is possible to raise total production significantly through diversification of farming systems, such as raising fish in rice paddies or growing crops with trees, or adding goats or poultry to household operations in many countries. Agroecological approaches increased the stability of production as seen in lower co-efficients of variance in crop yield with better soil and water management (Francis 1988).

It is difficult, however, to quantify all the potentials of such diversified and intensified systems because there is too little research and experience to establish their limits. Nevertheless, 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 (Altieri, 1995). In fact, most agroecological technologies promoted by NGOs can improve traditional agricultural yield increasing cereal output per area of marginal land from some 400-600kg/ha to 2000-2500 kg/ha. Enhancing also the general agrobiodiversity and its associated positive effects on food security and environmental integrity. Some projects emphasizing green manures and other organic management techniques can increase maize yields from 1-1.5 t/ha (a typical highland peasant yield) to 3-4 t/ha (Bunch 19). Polycultures produce more combined yield in a given area than could be obtained from monocultures of the component species. Most traditional or NGO promoted polycultures exhibit LER values greater than 1.5. Moreover, yield variability of cereal/legume polycultures are much lower than for monocultures of the components (Francis 1986).

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 farmers and their families; and ensure soil protection and conservation as well as enhance biodiversity (Pretty 1997). Table 2 list a series of agroecological projects in Latin America which feature substantial yield enhancements and spread of agroecological technologies among resource poor farmers.

Current limitations to the widespread use of agroecology.

With increasing evidence and awareness of the advantages of agroecology, why hasn’t it spread more rapidly and how can it be multiplied and adopted more widely? A key obstacle to the use of agroecology is the demand for specificity in its application. Contrary to conventional systems featuring homogeneous technological packages designed for ease of adoption and that lead to agroecosystem simplification, agroecological systems require that principles are applied creatively within each particular agroecosystem. 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 (Beets 1990). This does not mean however, that agroecological schemes adapted to specific conditions may not be applicable at ecologically and socially homologous larger sales. What implies is the understanding of 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 mobilized (DeWalt 1994).

On the other hand, technological or ecological intentions are not enough to disseminate agroecology. 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. 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.

A major challenge for the future entails promoting institutional and policy changes to realize the potential of the alternative approaches. 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 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 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.

Scaling-up of successful agroecological initiatives is needed in order to spread more widely the benefits of such sustainable agricultural projects. A basic question facing many policy makers, donors and even researchers is what do current advances in agroecology have in store for enhanced productivity, environmental quality and poverty reduction. Without knowing this, many are doubtful about whether it makes sense to increase the investment on agroecological strategies, and by doing so to scale-up projects that have already proved successful, thereby generating a meaningful impact in the income, food security and environmental integrity of wider populations. For many NGOs, existing subsidies and policy incentives for conventional chemical approaches must be dismantled, and stress the need for supportive policies that enable this agroecological approach to blossom. Others argue that participatory, farmer-friendly methods of technology development must be incorporated, ensuring that men, women, elders, and marginalized poor farmers or labor groups are included in development alternatives. Still others state that security of land is a fundamental condition for wider adoption of resource-conserving technologies. Whatever the constraint, the scaling-up of projects that have already proven successful will imply documentation of existing successful case studies so that principles underlying the success of local initiatives can be systematized and later applied in new areas, sperading benefits of local sustainable agriculture beyond project boundaries in both space and time. A starting point should be the understanding of the agroecological and socio-economic conditions under which alternatives were adopted and implemented. Such understanding can shed light on the constraints and opportunities farmers in other regions 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. For example, in Central America the further spread of soil conservation and soil fertility techniques may require an understanding of key principles of soil biology processes rather than merely promoting specific legumes or conservation techniques. What may be key is to identify multipurpose innovations with multiple effects including for example improved soil fertility, weed suppression and fodder production. In Cuba, more emphasis on participatory approaches and farmer networks may be the missing link to spread out the massive agroecological knowledge that the scientific community has developed since 1989. In Peru, creative marketing strategies and outlets may be key to turn initiatives that sprung from the grassroots in collaboration with the local governments into more economically viable operations.

A key issue related to the growing success of community-led agroecological initiatives is to understand the “bottlenecks” that impede that they flourish and spread. Many economists and policy makers demand that such initiatives be demonstrably economically viable before supporting them. The problem is that in most cases an enabling policy environment is missing and existing policy frameworks encourage high-input conventional agricultural technologies. The challenge is therefore to subject the selected cases to economic analysis that demonstrate the economic efficiency of alternatives and to assess the Green Revolution packet against agroecology without the hidden support of favorable price distortions. Preliminary studies conducted in Honduras indicate that resource-conserving technologies are economically competitive, and increase yields without the need for costly external inputs (Mausolff and Farber 1995). The challenge is how to take advantage of the decreased need for chemical fertilizers in agroecological systems in order to influence the adoption behavior of farmers with limited access to conventional sources of nitrogen.

Another possibility is that local-regional research and extension capabilities lack theoretical and practical skills on sustainable agriculture and therefore need to be strengthened and provided with training and skills on participatory methods and agroecology. Promotion of farmer to farmer exchanges through cross-visits, peer training, field days, etc. should be encouraged if non-existent, in order to widely foster information exchange and dissemination .

Is there a role for biotechnology in agroecological natural-resource management?

As explained before, in the past resource-poor farmers were bypassed by the Green Revolution, because their soil, water, and labor endowments were unsuited to the demanding and costly management practices of improved seeds and accompanying pesticides and fertilizers. Because these poor endowments persist, and the institutional infrastructure and low-interest credit to deliver emerging technologies to poor farmers is missing, it is expected that biotechnology will exacerbate marginalization even more, as such technologies which are under corporate control and protected by patents, are expensive and inappropriate to the needs and circumstances of indigenous farmers.

Moreover, poor farmers do not represent an interesting market for private corporations, which focus on biotechnological innovations for the commercial agricultural sectors of industrial and developing nations, where they expect a huge return on their research investment.

If, as expected, transgenic seeds continue to be developed and commercialized exclusively by private firms, based on legal systems granting strict or exclusive intellectual property rights (IPRs), poor farmers will continue to find transgenic seeds too expensive to purchase. The few that will have access to transgenic seeds will be hurt by becoming dangerously "dependent" on the annual purchase of such seeds. Surely, choices are also being denied to poor farmers when private industries insist upon IPR systems that deny on-farm seed multiplication options, an aspect that is of fundamental cultural importance to traditional farmers who for centuries have saved and shared seeds.

Some scientist and policy makers posit that a solution to the IPR and access problems would be to increase public sector investments in biotechnology research so those modern advances in molecular biology can benefit the poor. However, even larger investments in the indigenous scientific and institutional capacity of developing countries to shape biotechnology to suit the needs and circumstances of small farmers may not yield the desire results. Corporate IPR on the vectors and genes used in the plant transformation systems, selectable markers, gene expression technologies ,etc., is already affecting the development of transgenic crops by public institutions and in some developing countries the deployment of transgenic crops has been slowed due to IPR. Moreover, the seed distribution channels and agricultural extension to reach farmers are being privatized and mandated to focus on commercial rather than on poor farmers. To most poor farmers, NGOs are the only partners, that despite their limited resources, can offer them some viable options to solve agricultural limitations.

It is important however to note that appropriate applications of biotechnology to develop crops with desirable traits to small farmers such as enhanced competitiveness to weeds or drought tolerance would not be a panacea. Since traits such as improving the water use efficiency of crops are polygenic, development of crops with such traitscould take at least l0 years and once developed yield increases would only amount to 30-40 percent due to metabolic-physiological trade-offs that plants undergo once genetically modified. There could also be pleiotropic effects responsible for yield drag. The rest of the yield increases would have to come from environmental management activities directed at improving the overall farming system (i.e. enhancing soil cover or soil organic matter for improved water retention) rather than genetically manipulating specific commodities. Here lies the fundamental reason of the importance of NRM and the role that biotechnology should play as one more possible tool to complement NRM as needed.

Many scientists in private and public institutions are focusing on biotechnology innovations to increase the nutritional content of crops thus potentially serving as a better source of essential nutrients to the poor and hungry. Rice capable of producing provitamin A is being heralded as the best that agrobiotech can offer the developing world, but such innovations are blind solutions that ignore the root causes of why there are 2 million children at risk of Vitamin A deficiency, and also to the alternatives on how to provide Vitamin A to the poor. Moreover, it is critical to understand that in the rural areas of the developing world food preferences are culturally determined and that Asians will not likely consume "orange rice" in the midst of abundant white rice. In fact small Asian farmers maintain a diversity of rice varieties with varying nutritional contents and adapted to a wide variety of environmental conditions. The resulting genetic diversity heightens resistance to plant diseases and enables farmers to derive multiple nutritional uses. Moreover within and in the periphery of paddy rice fields there are an abundance of wild and cultivated leafy greens rich in Vitamin A. Although wild green vegetables have been regarded as peripheral to the peasant household, gathering as currently practiced in many peasant communities, afford a meaningful addition to the peasant family nutrition and economy. Such nutritional agrobiodiversity is threatened by the expansion of transgenic monocultures especially herbicide resistant crops subjected to heavy applications of broad spectrum weed killers such as glyphosphate.

Another problem for the application of biotechnology in developing countries is associated with the large-scale landscape homogenization accompanying the deployment of transgenic crops, which not only is incompatible with biodiversity rich cropping systems (i.e. polycultures, agroforestry systems, legume-based rotations, etc.) of small farmers, but that can also exacerbate the existing ecological problems already associated with monoculture agriculture and create new environmental risks. Although a certain degree of crop uniformity may have certain economic advantages, it has ecological drawbacks.

The uniformity caused by increasing areas sown to a smaller number of varieties is a source of increased risk for farmers, as the varieties may be more vulnerable to disease and pest attack and most of them perform poorly in marginal environments (Robinson 1996). All of the above effects are not ubiquitous to modern varieties and it is expected that given their monogenic nature and fast acreage expansion, transgenic crops will only exacerbate such effects.

There is strength in the agricultural diversity of developing countries, and it should not be inhibited or reduced by extensive monoculture. Moreover, in addition to having high levels of agrobiodiversity, many developing countries constitute centers of genetic diversity and in such environments the transfer of coding traits from transgenic crops to wild or weed populations of these taxa and their close relatives is expected to be high. Genetic exchange between crops and their wild ancestors is common in traditional agroecosystems and transgenic crops are bound to frequently encounter sexually compatible plant relatives, therefore the potential for "genetic pollution" in traditional agroecosystems is worrisome.

Similarly problematic are recent findings by ecologists who documented that the insecticidal toxin produced by Bacillis thuringiensis subsp. kurstaki inside Bt corn remains active in the soil after the crop is plowed under, where it binds rapidly and tightly to clays and humic acids. The toxin retains its insecticidal properties and is protected against microbial degradation by being bound to soil particles, persisting in various soils for at least 234 days. This is of serious concern to most poor farmers who cannot purchase expensive chemical fertilizers, and that rely instead on local residues, organic matter and especially soil microorganisms for soil fertility (i.e. key invertebrate, fungal or bacterial species) all of which can be affected by the soil bound toxin.

Small farmers also rely for insect pest control on the rich complex of predators and parasites associated with their mixed cropping systems. But research results showing that natural enemies can be affected directly through inter-trophic level effects of the toxin present in Bt crops (i.e. Swiss scientists observed higher mortalility of predaceous lacewing larvae reared on Bt corn-fed target and non-target prey) raises serious concerns about the potential disruption of natural pest control, as polyphagous predators that move within and between crop cultivars will encounter Bt-containing non-target prey throughout the crop season. Disrupted biocontrol mechanisms will likely result in increased crop losses due to pests or to increased use of pesticides by farmers with consequent health and environmental hazards.

Conclusions and recommendations.

Alternative agricultural development approaches and agroecological technologies spearheaded by farmers groups and NGOs around the developing world are already making a significant contribution to food security at the household, national and regional levels in Africa, Asia, and Latin America (Pretty 1995). Increasing smallholder agricultural productivity not only increases food supplies, but also increases smallholder incomes, reducing poverty, increasing food access, reducing malnutrition and improving the livelihoods of the poor. Yield increases are being achieved by using technological approaches, based on agroecological principles that emphasize diversity, synergy, recycling and integration; and social processes that emphasize community participation and empowerment (Rosset 1999). When such features are optimized, not only yield enhancement and stability of production are achieved, but also a series of ecological services such as conservation of biodiversity, soil restoration, water harvesting, improved natural pest regulation mechanisms, etc (Altieri et al 1998).

Agroecological approaches are increasing production under environmental conditions that are far from ideal, such as on eroded hillsides of Central America, high barren plateaus of the Andes, semi-arid areas in the West African Sahel, exhausted lands in eastern and southern Africa, sloping areas in the Philippines and remote forest margins in many parts of Asia. That yields can be doubled or more in these areas is due in part to the low base of production from which these farmers start. However, absolute yield levels can also become high. These are areas where the need to increase production is greatest and where the soil, climatic and other conditions are most unfavorable. So relative to the poor resource endowments and the urgent human needs, the levels of production being newly achieved are quite significant, and they provide food directly to households that are most vulnerable to food insecurity. These experiences which emphasize farmer to farmer research and grassroots extension approaches, represent countless demonstrations of talent, creativity, and scientific capability in rural communities. They point to the fact that human resource development is the cornerstone of any strategy aimed at increasing options for rural people and especially resource-poor farmers.

Promising research areas for evaluation and promotion of alternative technologies and policies include: green manures, cover crops, polycultures, improved fallows, agroforestry, aquaculture, crop-livestock mixed systems, IPM, biological control, organic soil management and nutrient cycling, processes of technology adaptation and adoption, supportive policies, institutional partnerships and market development.

Results from agroecological inititiatives are a breakthrough for achieving food security and environmental preservation among the rural poor in the developing world, but their potential and further spread depends on investments, policies, institutional support and attitude changes on the part of policy makers and the scientific community, especially the CGIAR and GFAR which should devote much of its efforts to assist the 370 million rural poor living in marginal environments. But the task must be shared with NGOs and farmers organizations.

The ideal way to achieve a qualitative leap in agroecological research is to promote partnerships amongst the various stakeholders in agricultural development processes. One can imagine a variety of combinations amongst the following players: researchers, farmers, officially and NGO-employed extension agents, produce processing and marketing companies, companies supplying inputs (including small seed companies) and equipment, representatives of official programs, credit agents, environmental organizations, etc. Their roles will be quite differentiated, as will be the intensity of their inter-relations, but all will have a say about what products will reach the market, and how. Such partnerships must not be reduced to local alliances amongst partners in a development process, but must encompass broader national and international networks dealing with similar sets of problems, even in differing ecological realities. NGOs have already created such networks of alliances quite effectively, and their experience can be broadened to incorporate many more partners.

Clearly the new kind of pro-poor research will demand paradigmatic and methodological changes, as well as a capacity to intensify interdisciplinarity, in order for development workers to be able to balance ecological, agronomic, economic, cultural and social concerns. In addition to obvious changes in the profile of researchers and extension agents themselves, there must be changes in institutional procedures, to make them more flexible and decentralized, and to modify today's prevailing systems of professional evaluation, which are a major limitation for interested researchers to be able to move towards agroecological approaches.

Failure to promote a people-centered agricultural research and development due to diversion of funds and expertise to biotechnology will forego a historical opportunity to raise agricultural productivity in economically viable, environmentally benign and socially uplifting ways.

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TABLE 1: Basic technical elements of an agroecological strategy.

1. *Conservation and Regeneration of Natural Resources*
   A. Soil (erosion, fertility, and plant health)
   B. Water (harvesting, in-situ conservation, management, irrigation)
   C. Germplasm (plant and animal native species, land races, adapted germplasm)
   D. Beneficial fauna and flora (natural enemies, pollinators, multiple use vegetation)

2. *Management of Productive Resources*
   A. Diversification
      -temporal (rotations, sequences, etc.)
      -spatial (polycultures, agroforestry, crop/livestock mixed systems)
      -genetic (multilines, etc)
      -regional (zonification, watershed, etc.)

   B. Recycling of nutrients and organic matter
      -plant biomass)green manure, crop residues, N fixation)
      -animal biomass (manure, urine, etc)
      -reutilization of nutrients and resources internal and external to the farm

   C. Biotic regulation (crop protection and animal health)
      -natural biological control (enhancement of natural control agents)
      -artificial biological control (importation and augmentation of natural enemies, botanical insecticides, alternative veterinary products, etc.)

3. Implementation of Technical Elements
   A. Definition of resource regeneration, conservation and management techniques tailored to local needs and agroecological-socioeconomic circumstances.
   B. The level of implementation can be at the microregion watershed level, farm level and cropping system level.
   C. The implementation is guided by a holistic (integrated) conception and therefore does not emphasize isolated elements.
   D. The strategy must be in agreement with the peasant rationale and must incorporate elements of technical resource management.

<u>TABLE 2</u>: Extent and impacts of agroecological technologies and practices implemented by NGOs in peasant farmin systems throughout Latin America

Country	Organization Involved	Agroecological Intervention	No. of Farmers or Farming Units Affected	No. of Hectares Affected	Dominant Crops	Yield Increases (%
Brazil	EPAGRI AS-PTA	Green Manures Cover Crops	38,000 Families	1,330,000	Maize Wheat	198 – 246 %
Guatemala	Altertec and others	Soil Conservation Green Manures Organic Farming	17,000 Units	17,000	Maize	250 %
Honduras	CIDDICO COSECHA	Soil Conservation Green Manures	27,000 Units	42,000	Maize	250 %
EL Salvador	COAGRES	Rotations Green Maures Compost Botanicals	>200 Farmers	nd	Cereals	40 – 60 %
Mexico	Oaxacan Cooperatives	Compost Terracing Contour Planting	3,000 Families	23,500	Coffee	140 %
Peru	PRAVTIR CIED	Rehabilitation of Ancient Terraces	>1250 Families	> 1000	Andean Crops	141 – 165 %
	PIWA-CIED	Raised Fields	nd	250	Andean Crops	333 %
	CIED	Watershed Agricultural Rehabilitation	>100 Families	N/A	Andean Crops	30 – 50 %
	IDEAS	Intercropping Agroforestry Composting	12 Families	25	Several Crops	20 %
Dominican Republic	Plan Sierra Swedforest-Fudeco	Soil Conservation Dry Forest Mgmt. Silvopastoral Systems	>2,500 Families	>1,000	Several Crops	50 – 70 %
Chile	CET	Integrated Farms Organic Farming	>1,000 Families	>2,250	Several Crops	>50 %

Cuba	ACAO	Integrated Farms	4 Cooperatives	250	Several Crops	50 – 70 %

Nd= no data
Source: Browder 1989, Altieri 1995, Pretty 1997

<u>TABLE 3:</u> Examples of promising research themes relevant to resource–poor farmers

- Improved understanding of the ecological workings of selected critical agroecosystems located in marginal environments.
- New varieties produced through conventional breeding and genetic engineering that does not cross species barriers, that deliver higher yield stability in the face of environmental stress.
- Technologies for drought prone rain-fed rice cultivation.
- Small-scale, community-managed irrigation and water harvesting and conservation systems.
- More productive cereal-based farming systems.
- Improved agroecological systems appropriate to specific acid- and mineral- deficient soils.
- Synergistic cropping and crop- livestock systems providing higher, more stable yields.
- Productive and sustainable agroforestry alternatives to shifting cultivation.
- Sustainable income- and employment- generating exploitation of forests, fisheries, and other natural resources.