Foreword

The Conference on Sustainable Agriculture, held at the Rockefeller Foundation's study and conference center, Villa Serbelloni at Bellagio, Italy, in April 1999, grew out of lively discussions at a workshop on future world food requirements organized by the Keystone Center in March 1997 at Airlie House in Warrenton, Virginia. Quite divergent opinions were expressed on whether further expansion of "modern" agriculture, with its reliance on chemical and energy inputs and with concomitant environmental impacts, should — or even could — be expected to double world food production in the next 30 years or so.

Miguel Altieri, from the Department of Environmental Science, Policy and Management at the University of California, Berkeley, and Norman Uphoff, director of the Cornell International Institute for Food, Agriculture and Development (CIIFAD), discussed with Robert Herdt, director of Agricultural Sciences for the Rockefeller Foundation, the value of conducting an assessment of "alternative" agricultural systems of production. To what extent can such systems be expected to make major contributions to world food supply in the future? If these systems are simply "greener" than are "modern" agricultural practices, they will not be able to help meet global food security needs.

A proposal that Altieri and Uphoff prepared for a conference to evaluate these questions was accepted by the Rockefeller Foundation's Bellagio Committee in early 1998. This meant that the Foundation would cover all of the costs of food, lodging and logistical support for holding the conference at Villa Serbelloni. The World Bank's Rural Development Department provided a grant to cover the travel costs for some of the participants from developing countries. Several international organizations covered the travel costs for their staff: the Plant Protection Service of the U.N. Food and Agriculture Organization (FAO); the International Centre for Research in Agroforestry (ICRAF); the International Center for Living Aquatic Resource Management (ICLARM); the International Food Policy Research Institute (IFPRI); and Resources for the Future. CIIFAD covered the balance of expenses and contributed the administrative support needed to organize the conference. The organizers would like to thank all of these institutions for their support which made this conference possible, and Virginia Montopoli for managing the planning and operation of the meeting so well.

Altieri prepared a conference declaration that was circulated at a meeting of the Consultative Group for International Agricultural Research (CGIAR) in Beijing in May 1999. Uphoff drafted this conference report which was circulated to all participants for comments and improvement. Altieri is editing a special issue of the journal *Environment, Development and Sustainability*, which will contain many of the case studies prepared for the conference. Uphoff is editing a book that will integrate the substance of the papers, discussions and conclusions into a volume that elaborates upon and documents the ideas presented here.

— Miguel Altieri and Norman Uphoff

This report summarizes the discussions and conclusions of an international conference held to assess the potentials of agroecological approaches to raising agricultural production on a worldwide scale. The papers prepared for and discussed at the conference are being revised and integrated to produce a book that identifies and assesses opportunities for contributing to future world food needs. It will provide more detail on the case studies and explore the implications of the exchange of views and experience among diverse participants (see Annex).

New agricultural technologies developed and extended over the past three decades have contributed to unprecedented growth in world food production. Without the fruits of the Green Revolution, there would be large food deficits, or adverse environmental impacts of bringing large areas of less suitable land under cultivation. But there is growing concern that this pattern and path of agricultural development, which has costs as well as benefits, may not be the best or the only one to promote in the future (Conway 1997).

Can future world food needs be met by more of the same kind of agricultural investments promoted over the past three decades — through research, extension, infrastructure and policies? Or should policy-makers and producers be looking also for other ways that are environmentally sustainable, economically efficient, and socially just that could increase world food supplies? Do such alternatives exist? What are the potentials of production strategies that rely more on better management than on investment of capital, more on local resources than on external inputs, and more on biological processes than on chemical applications?

That food production will need to be increased substantially in the future is not doubted. This makes greater public and private investments in agricultural research and extension both well justified and indeed critical, considering how long are the lag times before new practices are widely adopted and fully exploited.

Considering innovative programs reported from Africa, Asia and Latin America made it clear that a greater — and to the extent that it is justified by results — a growing share of agricultural research and extension efforts should be focused on approaches and strategies that are based on agroecological concepts and concerns.

These offer opportunities to increase food production not just by increments but often by multiples. As seen from the case studies, better combinations of plant, soil, water and nutrient management, with livestock or fish integrated into farming systems and with integrated pest management processes, are frequently achieving production increases of 50 to 100 percent or more in a wide variety of circumstances, including some that are agriculturally quite adverse.

The central message from the conference — for governments, researchers, donor agencies and farmers — is that there are numerous alternatives to mainstream agricultural research and development that are worth investigating and supporting. Indeed, taking these alternatives seriously — and refining, adapting and disseminating them — may determine whether the people of this world can successfully meet their needs for nutrition and at the same time maintain a livable natural and social environment in the 21st century.

The Situation

Projections differ regarding exactly when in the next century food producers around the world will need to be achieving twice the present level of agricultural output to meet the requirements of a larger and, everyone hopes, more prosperous population. There are also large, presently unmet food needs that a humane world will not leave unattended.

Few doubt that such a huge increase 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?

Technological Contributions

This question has been answered optimistically by pointing out that the output of the major cereal grains (rice, wheat, maize) has been doubled over the past 30 to 35 years. This remarkable and unparalleled acceleration in food production was achieved by using the technologies of "the Green Revolution" — improved seeds of high-yielding varieties, irrigation, fertilizers, and other agrochemicals (Crosson and Anderson 1999).

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, we are beginning to see some adverse environmental impacts from production that is chemical- and fossil fuel-intensive.

By the middle of the next century, there will be about one-third less arable land available per capita, and at least an equivalent reduction in the availability of water for agricultural purposes. Major increases in both land and water productivity will be needed if food supply is to be doubled with less of both these key natural resources available. Also, unless great efforts are undertaken and successful, there will be continuing reductions in biodiversity, which is the source for genetic material needed to make further advances in plant and animal breeding. There could also be accelerated global climate change.

Biotechnology is being regarded by some as a means for achieving large future increases in agricultural production. But major benefits from biotechnology remain still largely over the horizon. And given the incentives and predominance of the private sector in this domain, few biotechnology investments are currently aimed at increasing yields (Ruttan 1999). There could yet be some advanced technological breakthroughs that transform production possibilities in agriculture. But given the critical importance of food to human well-being and to maintaining economic vitality, it is hardly advisable to put all of our agricultural eggs in the biotechnology basket. Neither the traditional "mainstream" paradigm nor the biotechnology paradigm therefore appear to be sufficient.

Changes in Population Growth and Demand

Some good news is that the rate of population growth is beginning to slow globally, in some places quite dramatically. For example, the average number of children born to women in Bangladesh has declined from 6.2 to 3.4 in just a decade's time, and population growth rates are now dropping in most developing countries. But the previous rapid population expansion has given the world quite a young age structure, with billions of men and women now in or entering their most fertile years.

Demographers have scaled back their estimates of expected maximum human population, from an earlier anticipated peak of 15-18 billion to 9-10 billion. But even this reduced additional growth will mean there will be half to two-thirds more people on earth than now live here. Almost all of the population added will be in the less-developed countries, with a large share of their population poor and likely to be undernourished.

According to FAO estimates, there are presently about 800 million persons on earth who are living with perpetual hunger and malnutrition (Pinstrup-Andersen and Cohen 1999). Ensuring food security for them and their descendents will be more difficult to the extent that overall food supply is not growing sufficiently. The way in which food is produced should contribute to its meeting the needs of those who are most food insecure.

As population growth slows, the strongest force increasing demand for more agricultural production will become rising incomes, which is the objective of all governments and almost all individuals. Although richer persons spend smaller proportions of their income on food, in total they generally consume more food, and richer food, which contributes to different kinds of illness and debilitation.

Changes in diet that usually accompany higher incomes will require much greater increases in the production of feed grains, not just food grains, as foods of animal origin partly displace those coming from plants. It is thus probably a conservative estimate to say that in order to meet economic and social needs within the next three to five decades, the world should be producing at least twice as much food as at present.

Economic and Distributional Considerations

Simply increasing food supply will not by itself assure food security to all households, communities and nations. More favorable distributions of income and food are essential for food security, as access to food is ultimately mediated by purchasing power, however this is obtained.

Poverty is the main and most immediate cause of hunger, not inadequate supply. This does not change the fact, however, that adequate food supply remains a necessary if not sufficient condition for eliminating hunger and poverty.

To the extent that the poor are poorly fed, they are too weak and prone to disease to make the most of whatever resources they have. This reduces their bargaining power so that they are more poorly compensated for their labor, regardless of skill levels (Hart 1986).

Whenever there are food shortages, it

is the consumption of the poor that is curtailed. Figuratively, and sometimes literally, they stand "at the end of the queue," with food distributed from the top of this socioeconomic hierarchy. When all of the food that is available has been given out, those persons who remain in line must go hungry.

Moreover, whenever demand exceeds supply, food prices go up, sometimes drastically. This reduces real income, and it especially shrinks the meager incomes of the poor while also pinching the modest incomes of the middle class.

Clearly, socioeconomic and policy issues need to be resolved to reduce poverty and hunger. But concern with increasing supply is justifiable in both practical and ethical terms. Those who are underfed need adequate food and good nutrition to achieve their productive and human potentials, which will benefit not only themselves but also others in their societies.

To the extent that agricultural productivity lags and food shortages ensue, those who are well-fed will find that the growth of economies on which their well-being depends must decelerate. Resources that could be devoted to other investments and consumption will have to be diverted to meeting basic food needs. Capital investment in expansion of non-agricultural sectors will have to diminish to the extent that the world becomes less able to feed all of its inhabitants.

The Challenge and Opportunity

Conventional wisdom currently holds that this doubling of food supply is possible — and in the opinions of some, will only be possible — through redoubled efforts to "modernize" agriculture worldwide. The success of "high-tech" mainstream agriculture with its mechanization of production, its reliance on fossil fuels for both power and agrochemicals, and its large investments of capital per worker and per hectare has created a presumption in governments, research institutions and donor agencies that "more of the same" is the best, and maybe only, strategy for increasing world food production.

In fact, there are a variety of alternative approaches to mainstream practices and technologies, not just a single contrasting approach. Also there are some important potential complementarities between different kinds of agricultural practices.[1] So the term "alternative agriculture" is not very satisfactory. The designation "sustainable agriculture," though widely used and indeed used by many conference participants, is also contestable because sustainability is contingent on many factors rather than being inherent in any particular practice or farming system.

Few if any systems can remain robust under any and all possible adverse conditions. Also, it is easier to suggest what is

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[1]*For example, chemical fertilizers and inputs of organic matter (composts and green manures), often regarded as competing alternatives, can each be made more productive by adding appropriate amounts of the other kind of nutrient (e.g., Palm et al. 1997; Schlather 1998).*

likely to be unsustainable than to know what will retain its productivity indefinitely. So conference participants agreed that concepts and terminologies that array different practices and technologies, and their proponents, in opposing camps — rather than along continua — do a disservice to the principles and purposes as well as to the people involved.

Proponents of Green Revolution technologies can point to many benefits resulting from those innovations. The declining real price of cereal grains over the past three decades has made a major contribution to increased food security around the world (Conway 1997). But this technical progress has bypassed many millions of households for whom the technologies were not well suited because of environmental, infrastructural, social, or other conditions. Moreover, these technologies, particularly when utilized in large "industrialized" systems of agriculture, can create environmental problems that undermine ecosystems and human health.

An estimated one billion people — one-sixth of the world's population, and a much greater percentage of the poor — live and work in situations where their farming, herding or fishing operations cannot benefit much from mainstream agricultural technologies. Factors such as landholding size, inadequate rainfall or groundwater, poor soil fertility, unfavorable topography, and remoteness from markets, infrastructure and institutions make these technologies unavailable or not appropriate. This should come as no surprise since most modern technologies have been developed and tested to succeed under more-favored rather than under less-favored conditions.

Pusing Pizon, plowing his small rainfed paddy in the Philippine uplands, is typical of millions of small farmers in the developing world who have not benefited from modern agricultural technologies because their parcels of land are too small or remote, their soils are too poor, or they cannot afford the inputs.

Even in some of the better-endowed areas, the sustainability of these mainstream technologies is now problematic. Water depletion and soil erosion have already emerged as serious problems for industrial agriculture. Falling water tables in the Indian Punjab, in the North China plains, and in the Great Plains of the United States, for example, could shut down "thirsty" production practices in the decades ahead. Controls are having to be placed on modern agriculture to reduce chemical runoffs, residues and toxic nutrient build-ups from use of agrochemicals and chemical fertilizers, especially the application of large quantities of inorganic nitrogen.

But the conference did not convene to evaluate the future potentials and limitations of Green Revolution technologies. The data and analyses considered at Bellagio dealt with the potentials and problems of various alternatives or complements to these more capital-intensive approaches to raising agricultural production.

New Approaches to Agricultural Innovation

The most central feature of the approaches we considered is that they are based on agroecological thinking, either explicitly or tacitly, to achieve increased production. This means they capitalize on the processes of biology and nature more than relying primarily on chemical, engineering or genetic innovations.

Agroecological approaches seek to create optimum growing conditions for plants and animals not as individual specimens but as parts of larger ecosystems, where nutrients and other ecological services are provided and recycled in mutually supportive ways (Altieri 1995). In particular, the soil is not regarded as a repository for production inputs or a terrain to be exploited and mined, but rather as a living system with micro- and macro-organisms interacting with organic and mineral matter.

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.

Like good producers everywhere, small and marginal farmers must strive to optimize their production within the actual constraints that they face. Although they have immediate and urgent needs for production (a high time discount rate, to use economists' terminology), most know that they need to conserve the resource base on which their production possibilities depend.

The conference considered a wide variety of production systems, not best understood simply as "technologies." In such systems, a considerable range of inputs and outputs are managed with multiple objectives in mind. More favorable policies are often as critical for success as are improved technologies, and in all the successful systems we found training and other opportunities for the upgrading of human capacities.

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 on the paddy bunds in Bangladesh, or adding goats or poultry to household operations in many countries. Agroecological approaches increased the stability of production as seen in lower coefficients of variance in crop yield with better soil and water management (Francis 1988; also data from several of the case studies). 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.

How sustainable such production systems will be cannot be determined at present because many are fairly recent in use. But the practices employed seek to replenish nutrient supplies and to sustain soil health and biodiversity. There is thus no reason to think that these new systems should be less sustainable than those that rely heavily on chemicals, mechanization and other external inputs. A number of agroecologically-based systems are reported below, some of which have sustained several doublings of yield over 25 to 50 years.

Agroecological systems are not limited to producing low outputs. Increases in production of 50-100 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 — are being increased by several-fold.

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, rainforest margins of Madagascar, heavily populated areas of Malawi, crowded flood plains of Bangladesh, within the war zone of Sri Lanka, and on sloping areas in the Philippines and remote forest margins of Indonesia.

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.

It is good news, though economically logical, that the scope for relative gains in output appears greatest where output is currently low. Still, some large absolute increases have been obtained as well. Some of the most impressive results from these new approaches are being achieved in Africa, a continent with serious food deficits and major constraints. With due attention to soil, nutrient and water management, substantial expansion of production is surely attainable there.

Not all agricultural innovations will work under all sets of conditions, for example, where the soil lacks certain nutrients or rainfall is too little or too unreliable. However, good agroecological practices can deal with such constraints and reach some reasonable level of production. Some of these practices indeed enhance soils' nutrient status and water-retaining ability, introducing possibilities for soil restoration or reclamation. Hardy leguminous species such as canavalia and tephrosia can be grown, and even enrich the soil, where it seems impossible that any plants will grow.

Where the labor supply for agriculture is limited, some of these innovations will not be practical because they require more labor. However, for example, intercropping velvet bean (mucuna) as a slashed-and-mulched cover crop with maize reduces labor requirements at the same time that it protects the soil from erosion and enriches it through the fixation of nitrogen by leguminous plant roots, raising yields by 35-40 percent (Thurston et al. 1994).

All of the technologies we considered are management- and knowledge-intensive, and most take considerable time to develop and diversify to users' satisfaction. Success depends in large part on the enhancement of human abilities to make decisions, manage resources, acquire information, and evaluate results. Although such activities are conventionally regarded only as a cost of production, when farmers engage in them, their levels of skill, knowledge and decision-making are increased. This enables farmers to be more productive in the future.

So activities that enhance human resources should be regarded as *benefits* for farmers, not only as *costs*. Practicing agriculture with greater management- and knowledge-intensity and engaging in experimentation and evaluation, which augments human capital in the farming sector, is a more progressive kind of agriculture. It also has the effect of giving farmers greater confidence and skills to solve problems and advance their interests.

Emphasis on Process

A principal conclusion from the conference concerned not the technologies and production systems examined, but rather the processes by which new agricultural practices are developed, improved and extended. These new approaches have emerged largely from experience and experimentation, much of it by farmers themselves, often stimulated by working with non-governmental organizations (NGOs), research institutions and universities. In some cases, government agencies have begun working in new, less directive and more collaborative relationships with farmers.

By and large, practice is ahead of theory in this area, though agroecology provides a basic and valid theoretical foundation for comprehending and assisting these changes in production practice. What are now considered innovations are often not really new, at least not to farmers.

Agroforestry, for example, which was "discovered" by donors, researchers and governments in the 1970s, is almost as old as agriculture itself, wherever perennial plants have been combined with annual crops and animals. (This was one reason for the subtitle of our conference, which juxtaposed new paradigms with old practices.) Agroforestry has become a new applied science in the field of natural resource management (Izac and Sanchez 1999).

As discussed more below, there is an emerging methodology for agricultural innovation that is as important as the technologies that result from it. This approach is based on active farmer involvement — indeed, often farmer leadership — in a process of identifying problems and needs to start and guide the process; of determining and choosing among possible solutions; of testing, monitoring and evaluating the results of new practices; and of helping to disseminate those results that are considered beneficial. This process can be characterized as participatory technology development, as farmer-centered research and extension, or as farmer-to-farmer agricultural improvement.

This methodology is more important than any particular technology because sustainable agriculture requires continuing adaptation and change in practices and strategies. This is necessary to meet changing environmental, economic and other conditions that affect the productivity and profitability of specific activities and crops.

A Dominican farmer (right) talks with a university researcher about his experimentation with cover crops. A key element in the development of alternative agricultural technologies is the active involvement of farmers.

Thus, the new approaches are distinguished as much by the way they are developed with, by and for farmers, as by the technologies themselves. Local knowledge is complemented and elaborated by the knowledge that scientists and researchers can bring to a collaborative process of advancing technological possibilities.

There is particular need for innovation among households that have been bypassed by Green Revolution options. For their food security problems to be solved, the means for raising production must be within the reach and comprehension of these farmers themselves.

Where Should Efforts Be Focused?

The Green Revolution made most of its productivity gains where they were easiest to reach, in areas with the better soils and climatic conditions, with more developed infrastructure, and generally with more educated and advantaged farmers. The greatest challenge now is to engage and benefit less-endowed areas and people.

Such regions and persons are commonly described as "marginal." This term appropriately refers to those on the margins of more prosperous farming areas and the economic mainstream. The term often implies, however, that these people and places are unproductive and thus not worth investing in.

This view is taken by some as a justification for ignoring such areas or assisting them only as a matter of charity, not with any expectation of raising their productivity significantly. Others, including the international research community, view marginal areas as presenting opportunities for making major improvements in food security, poverty reduction, and environmental conservation in a series of win-win situations.

There is growing evidence from economic research that directing investments principally to better-endowed areas and populations is empirically unsupported. Because there has already been considerable investment in the more-favored areas, they face diminishing returns to inputs of capital.

Accordingly, it should not be surprising that investments in the poorer areas, seriously undercapitalized, can produce greater marginal returns than investments in richer ones (Hazell and Fan 2000). While the last are not about to become first in absolute terms, with appropriate investments, i.e., suited to their conditions and needs, they can become considerably more productive in relative terms.

What will be appropriate investments? Only in special cases will technologies that were developed for favored areas under different conditions be very productive in poorer and marginal areas. As a rule, new technologies will have to be modified, adapted or often evolved *de novo* from existing knowledge and practices.

The possibilities for "transfer of technology" from favored to marginal areas were discussed in the conference. This was considered usually an inappropriate concept for the latter, where one has to deal with much greater variety and variability. There, technology has to be fitted and adapted more extensively than where good soils and climate favor monoculture and large capital investments.[2]

Whether a technology will be sustainably productive or not depends on local conditions, and such conditions vary widely and also change. The development of more appropriate and productive agriculture under diverse and changing circumstances will be more successful to the extent that rural people are actively involved in structuring and managing the process.

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[2] A few examples were cited of technology transfer that has been clearly beneficial, such as vaccinations against communicable disease or inexpensive, durable handpumps for village water supply. Such examples, however, were more from the areas of health and infrastructure than from agriculture, which requires more adaptation.

Engagement in such a process will increase their knowledge, skills and confidence, making them better able to deal with future problems and challenges, whether these are in the domain of agriculture or outside it. Especially with the growing and strengthening forces of globalization in the economy and culture, it is crucial that farmers have more capacity for continuous change and adaptation, given that there are no permanent technological solutions.

Agroecological Principles

We found our discussion continually moving back and forth between biophysical considerations and socioeconomic ones. Indeed, an ecological perspective should make clear that no factors can be understood in isolation from each other. Progress requires us to be analytical, critical, and evaluative in our thinking, but also to make syntheses and acquire holistic understanding.

A number of key agroecological principles were discussed as they apply to raising agricultural productivity in a sustainable manner (Altieri 1995):

- *Biodiversity* at all levels, to maintain greater resilience and richness within ecological systems;
- *Synergy* to achieve more output from given inputs thanks to mutually reinforcing interactions among crops, soils, insects, plants, animals, microorganisms, etc.;
- *Dynamics*, recognizing and capitalizing upon the continuous change in living things and systems, such as the process of nutrient recycling;
- *Enhancement* to add to the value and productivity of resources, such as by maintaining better soil health;
- *Conservation and regeneration* to minimize losses from systems and to strengthen them according to the preceding principles; and
- *Adaptation and innovation* to meet changing conditions in the environment and devise continually new ways of solving problems.

It should not be surprising that investments in the poorer areas, seriously undercapitalized, can produce greater marginal returns than investments in richer ones.

From our discussions, it was evident that the principles of agroecology are also appropriate for understanding how to gain more productivity from socio-cultural-economic systems at community and local levels and from political-economy systems at the national level and beyond.

Diversity, for example, is a principle that applies beyond the realm of ecosystems, as cultural diversity offers benefits similar to those from biodiversity. Synergy is seen in these other realms when positive-sum solutions are arrived at by consultation and accommodation of multiple stakeholder interests.

An agroecological approach expands horizons for analysis and intervention, taking whole landscapes or associations of flora as the focus rather than just a particular field or crop. Pest and disease control, for example, can be improved by maintaining more diverse sets of crops and non-crop plants and by having hedgerows or border plantings. Also, although intercropping will not achieve the highest yield possible for a particular crop, the productivity of the cropped area can be considerably increased in this way.

An agroecological approach also seeks to maintain the continuous flow of ecological services from the landscape, including cropped, grazed or fished areas. Protecting soil from erosion, retaining and storing water, filtering it to improve its quality, harboring fauna that pollinate flora, buffering temperature changes, and other services are given little consideration, let alone compensation, in the way agriculture is usually conceived, evaluated and managed.

Mainstream agriculture has sometimes become a threat to the environment where chemical dependence and monoculture prevail on a large scale. Agriculture should be at least benign with regard to the environment and wherever possible have beneficial effects.

Fortunately, agriculture can be designed and practiced in ways that augment productive potential rather than deplete it (Power 1999). Agroecological approaches that enlist the recuperative powers of plants and microorganisms can help to restore areas not previously, or no longer, productive.

Examples of Innovative Agricultural Approaches

It was evident from the case studies and comparative analyses presented to the conference that utilizing biological processes and potentials is not a “backward” kind of agriculture. The summaries below provide a sampling of the experiences shared by participants in their papers.

Africa

Kenya

In the semi-arid Machakos district, over a 60-year period, households invested in a variety of land improvement practices coupled with changes in cropping patterns in response to market opportunities. The practices included terraces, confining cattle and use of their manure, tree planting and hedgerows, water harvesting in ponds and other structures. Most were developed by farmers and carried out largely without government direction or support. They enabled households in Machakos to raise their agricultural productivity per hectare by 11 times, well ahead of the five-fold increase in population during this time (Tiffen et al. 1994).

According to Tiffen (1999), “The type of farming practised in the 1990s required much more judgment, knowledge and information than the older subsistence-oriented system of the 1930s.” The many and substantial changes made by farmers in their production systems can be seen from the following table, which shows how active farmers have been as innovators.

Main farm cash income sources in Machakos District, Kenya, 1995-1990

Village	1945	1960	1990
Kagundo	wheat, grams, coriander, sugar, bananas, other food crops, cattle, milk	fruit, vegetables, coffee	coffee, French beans
Mbooni (men)	livestock, sugar, bananas	sugar, English potatoes, wattle, livestock	coffee, vegetables, trees
Mbooni (women)	livestock, food crops	food crops, livestock	coffee, vegetables, handicrafts
Masli (men)	cattle, millet	livestock, millet	cotton, fruits, beans, pawpaws, tomatoes,maize, livestock
Masli (women)	ghee, cattle	goats, cattle	peas, beans, maize, mangoes
Makueni	—	goats, peas, beans, maize, grams	fruits, cotton
Ngwata (men)	—	(1965-70) charcoal, honey, ivory	maize, beans, livestock, pigeon peas, cotton, grams
Ngwata (women)	—	remittances and help from home	grams, sorghum, cowpeas, charcoal, livestock

Source: Interviews with village leaders in 1990, reported in Tiffen et al. (1994), Table 10.1.

Madagascar

The system of rice intensification (SRI) being promoted by Association Tefy Saina, a Malagasy NGO, was developed by a French priest who worked and experimented with farmers in this country during the 1970s and 1980s. By changing plant-soil-water-nutrient management practices, it greatly increases yields of rice, even on very poor soils. The changes are fairly radical: seedlings are transplanted when they are very young, singly rather than in clumps, and with wide spacing. During the vegetative growth stage, soil is intermittently watered and dried rather than keeping standing water on the field.

Where yields of irrigated rice have averaged about 2 tons per hectare, yields with SRI have ranged from 4 to 10 tons and even higher at a wide variety of elevations and rainfall levels, without requiring new seeds or applying chemical fertilizers. SRI methods give these results with any variety of rice, although some improved varieties, if well suited to the area, give yields in the 10- to 20-ton range. Compost is used wherever fertilizer is too expensive or not available (Uphoff 1999). Tefy Saina's name means "to improve the mind," as it uses experience with SRI to encourage greater experimentation among farmers.

Senegal

The Regenerative Agricultural Resource Center supported by the Rodale Institute, an American NGO, has developed measures with several hundred farmers in the semi-arid Thies region (average rainfall 400 mm) to prevent erosion of the soil from water and wind and to enhance soil fertility. The measures included introducing leguminous trees and shrubs as windbreaks and as sources of organic materials, intercropping and rotating leguminous and cereal crops, particularly peanuts and millet, plus use of manure and/or compost.

Farmer-managed trials in seven locations over a five-year period found that adding compost to manure increased peanut and millet yields by 53 to 74 percent. Compost and manure together gave yields 95 to 105 percent greater than those on control plots receiving neither form of organic nutrients (Diop 1999). Stone barriers to harvest water have been shown to increase the water-holding capacity of soil by 3 to 5 times within five years. Farmers are participating in the management of the Center as well as in their own farm improvement.

Mali

In Douentza district, an even more arid area with rainfall as low as 150 mm per year, a 9- to 11-month dry season, and frequent droughts, the Unitarian Service Committee of Canada has been working with 18 villages since 1987. According to Food and Agriculture Organization (FAO) standards for estimating food requirements, the district has been producing no more than 75 percent of its staple food needs even in better years.

A combination of soil and water conservation practices has shown that millet and sorghum yields can be reliably increased by 50 percent, which would make the population in this remote area at least self-sufficient. Water harvesting techniques protecting 4,000 hectares of arable lands have helped boost yields to as much as 1.7 tons per hectare, far above the level of 0.6 tons that had previously been considered a good yield. Vegetable gardens and fruit trees further contribute to food security in this remote area (Fofana 1999). These changes are all undertaken through discussion and planning with the communities.

Malawi

The International Center for Living Aquatic Resources Management (ICLARM) has been working with small farmers in this country to introduce aquaculture in an integrated manner. Farm ponds are not operated as separate production activities but are located next to vegetable gardens to utilize and recycle nutrient flows jointly. Hundreds of smallholders now produce on average between 1.35 to

1.65 tons of fish per hectare per year from their ponds. This is 50 to 80 percent more than the average yield for the 48 most productive specialized fish farms in southern Malawi, 0.9 tons (Brammett 1999).

The ponds, which are fed mostly with wastes from the vegetable garden and household, generate three times more net income for a household than its maize and other crops. The system is spreading farmer-to-farmer. A survey in Zomba district found that 80 percent of the farmers practicing integrated fish farming had never seen an extension demonstration. In Zomba East, where ICLARM worked with 34 farmers from 1991-95, there are now 225 practicing fish farmers. So this intensification is proceeding without further outside assistance.

A Malagasy farmer carefully transplants individual rice plants that she is cultivating according to the System of Rice Intensification (SRI), in which seedlings are transplanted when they are very young, singly rather than in clumps, and with wide spacing. With SRI, farmers are more than doubling and tripling their yields using their own seeds and no purchased inputs.

Nigeria

A long-term study of agricultural change since 1900 (Tiffen 1976, and 1999) documents how in Gombe, in the northern part of the country, low external input methods led to significant advances in yields. In particular, cattle manure was used to grow maize, cotton and other crops on an expanding scale.

In more recent years, however, these methods have been modified under the pressure of increasing population, fueled in part by the agricultural successes. Farmers now have to use substantial amounts of inorganic fertilizers. This case underscores the changefulness of agriculture. In 1967, maize was a minor crop; 20 years later, it represented a significant export to other regions of Nigeria.

Zambia and Kenya

The International Centre for Research on Agroforestry (ICRAF) has been trying to counter soil fertility constraints in Africa through a variety of means. During a two-year fallow period, the leaves and roots of leguminous shrubs accumulate about 200 kg of nitrogen per hectare. When these are incorporated into the soil, the land can support two or three subsequent maize crops with a doubling to quadrupling of maize yields (Sanchez 1999). About 10,000 farmers in Southern Africa are now using sesbania, tephrosia, gliricidia and other legumes this way. This practice gives them as much nitrogen per hectare as US$240 worth of fertilizer (Kwesiga et al. 1999).

Wild sunflower (*Tithonia diversifolia*), which has high concentrations of nitrogen, phosphorus, and potassium in its biomass, is now being used in Kenya to increase maize and vegetable yields (Buresh et al. 1997). Cash incomes of households can increase as much as 10 times with this organic source of fertility enhancement. Indigenous high-reactivity rock phosphates are used to overcome phosphorus deficiency in the soil. These technologies are considered as a means of empowerment, not just production. Sanchez (1999) cited one Zambian farmer as saying: “Agroforestry has restored my dignity. My family is no longer hungry; I can even help my neighbors now.”

Region-Wide Review

The Centre for Environment and Society at the University of Essex in the U.K. has conducted an assessment of projects or initiatives for sustainable agriculture alternatives across Africa. A review of 45 of these in 17 countries in Africa was presented to the conference (Pretty 1999). These projects or initiatives involve about 730,000 farm households with between 600,000 and 900,000 hectares of land under agroecological practices.

Maize and banana yield improvements in these various countries were generally 50 to 100 percent; sorghum and millet went up 30 to 100 percent; and potatoes went up 200 percent. The lowest yield increases were in the range of 5 to 10 percent. Additional benefits were diversification of production, particularly through vegetable gardens that produced throughout the year including the dry season, or production of fish from ponds, and the restoration of land for future production.

Latin America

Central America

The international NGO, World Neighbors, started working with communities around San Martin Jilotepeque in Guatemala in 1972, and around Guinope in Honduras in 1981. They have achieved some remarkable increases where farms are typically small (0.5 and 2.5 hectares respectively) and topography, soils and rainfall are quite limiting. Within seven and eight years, maize yields with the two programs went from 0.4-0.5 tons per hectare to 2.5 tons, a huge jump. Bean yields in this period advanced even more, from 0.15 tons to 0.85 tons. These increases were achieved through soil conservation measures, nutrient amendments — chicken manure, green manures and/or chemical fertilizers — and other improvements in management.

The strategy of farmer experimentation and farmer-to-farmer extension that these programs developed led to continuing self-managed increases in productivity. In the Guatemalan case, with no outside assistance after 1979 (and a raging civil war devastating the area), maize yields increased further to 4.5 tons per hectare by 1994, and in the Honduran case, to 3.7 tons. By 1994, the yields of beans averaged 1.35 tons per hectare across four villages in the two countries (Bunch 1999). The “farmer-to-farmer” approach developed through these programs (Bunch 1982) has been extended to other countries.

Andean Region

World Neighbors started working with rural communities in Peru in 1970 and in Bolivia in 1975. A subsequent program was initiated in Ecuador in 1989. Farmer experimentation and extension methods have been central to these programs. Once farmers in Peru became engaged in systematic testing and evaluation of different varieties of potatoes and barley, as well as of different cultivation practices, they found yield differences as great as 300 percent. This enabled them to make better choices and get more return from their land and labor. They also could see that varieties produced dramatically different results depending upon the particular environment in which they are grown.

In Bolivia, where rainfall averages only 500 mm in the high mountain areas, mostly illiterate farmers carrying out experiments with randomized plots and doing statistical tests of significance have found that differences in varieties and management practices produce great variations in potato yields. Test plots yield as high as 44 tons per hectare compared to the traditional average of 2 tons even under difficult soil and water conditions.

Potatoes are the main staple crop in the region. It has been known that using sheep manure on fields can raise yields up to 5 tons per hectare. Farmers working with World Neighbors learned through experiments that they could reach 8 tons by growing lupines as a green manure and then plowing this into the soil to increase organic matter and nitrogen. Combining lupines and sheep manure can push output even up to 12 tons. Cost of production calculations showed that about US$18 worth of lupine seed plus labor could produce about US$1,200 more value of potatoes (Ruddell and Beingolea 1999).

Brazil

This country has seen a very widespread adoption of green manures and cover crops (GMCC), which increase biological activity and water retention in the soil. An estimated 400,000 farmers are now using variations on this technology in southern Brazil. Some farmers use heavy mechanical equipment and herbicides, but others are developing more environmentally-friendly methods. Since 1987, maize yields have risen from 3 tons per hectare to 5 tons, and soybeans from 2.8 tons per hectare to 4.7 tons (Altieri 1999).

Maintaining soil cover this way greatly improves soil quality and involves considerably less labor. What species of legumes and what cultivation practices will work best is very location-specific, however, so much experimentation and adaptation are needed. A process of farmer experimentation is diffusing widely, assisted by NGOs and other organizations. Farmers themselves have been forming associations to facilitate sharing information.

Region-Wide Review

Since the early 1980s, more than 200 projects promoted by NGOs in Latin America have concentrated on promoting agroecological technologies that are suited to the complexities of peasant farming. Polycropping has been shown to have yield advantages of 20 to 60 percent. In Mexico, one hectare planted with a mixture of maize, squash and beans produces as much food as 1.73 hectares of land planted only with maize. A polycropped field also produces twice as much dry matter (4 tons vs. 2 tons), which can be plowed into the soil to retain fertility (Altieri 1999). Another advantage of such systems is their greater yield stability when weather varies, with a coefficient of variation on average 30 percent lower than for monoculture (Francis 1986).

The use of cover crops is spreading in Central and South America. In Nicaragua, the Campesino a Campesino movement has mobilized 1,000 peasants to recover degraded land in a watershed by planting leguminous cover crops. Chemical fertilizer use was reduced from 1.7 tons per hectare to 0.4 tons, while yields were increased from 0.7 tons to 2 tons per hectare, with 20 percent lower production costs (Buckles et al. 1998). In some places, cover crops are being disadopted because of changes in the economic environment, such as the opportunity cost of labor, but they are spreading into other areas where they are suitable to the biophysical and socioeconomic conditions (Neill and Lee 1999).

Asia

Bangladesh

The Rice-Fish Program, funded by the U.K.'s Department for International Development and the European Union and administered by CARE/ Bangladesh, is currently working with about 150,000 rural households to expand rice production within integrated farming systems that also practice integrated pest management (IPM) using few external inputs. The program aims to optimize the use of available natural resources through sustainable and more productive land use. By raising rice yields from 3.8 tons per hectare to 4.1 tons with 18-30 percent lower costs of production, incomes of participating farmers are 50 percent higher than those of control farmers in the area, who have similar assets but do not participate in the project.

Farming results have been stabilized, with variance in production reduced by about 50 percent compared to control farmers. Raising fish in farmers' rice paddies and growing vegetable crops on paddy bunds can add up to US$240 per hectare of income. This is twice as much income as earned from a hectare of rice production alone.

These practices have been evolved and communicated through Farmer Field Schools. These schools are highly participatory in their methods, following the example of the IPM program in Indonesia, developed over the past 10 years with FAO support (Oka 1997). The Rice-Fish Program is now scaling up to involve one million households starting next year (Dessilles 1999).

Sri Lanka

A similar program of integrated pest and crop management has been operating in this country with management by CARE and technical support from the Natural Resources Institute of U.K. Like the Bangladesh IPM program, this also uses the Farmer Field School methodology, which develops farmer's observational and analytical skills rather than just teaching them methods of pest control. In the 1997-98 season, rice yields of farmers using methods learned in the field schools were 11 to 44 percent higher than for untrained farmers in the same districts, with 38 to 178 percent greater net incomes due to lower costs of production.

The program covers vegetable crops as well as rice. Yield increases with IPM training for vegetable production have ranged between 7 and 44 percent, with income increases from these crops ranging between 12 and 129 percent.

There is rapid lateral spread, due to farmer-to-farmer diffusion. The results from 20 surveys indicate a 13-fold expansion in the use of IPM. With a total of 4,287 farmers trained, some 55,000 farmers are now using these methods (Jones 1999). This spread shows the potential for farmer-led dissemination of even complex technologies when users are actively engaged in understanding and adapting them, not just being trained to use them.

Indonesia

An indigenous farming system that is not widespread but very interesting are the complex "agroforests" in Indonesia, invented by local peoples over generations living on the margins of tropical rain forests. After some slash-and-burn preparation, food crops are planted along with tree seedlings that eventually shade out the crops, occupying different strata and producing high-value products such as fruits, resins, medicinals, and high-grade timber (Michon and de Foresta 1996).

These systems produce a higher standard of living for their managers than that enjoyed by households in the same area who only grow crops. Further, the populations of plants, birds and mammals associated with agroforests are nearly as extensive and diverse as those in adjacent undisturbed forests (Sanchez 1999).

Agroforests were not cited as an example of a farming system that can be widely expanded everywhere, but rather as an example of productive coexistence between agriculture and the natural environment, where people's well-being can be improved without sacrificing environmental integrity or services. They have adoption potential throughout the humid tropical forest margins.[3] For agroforests to remain viable, however, they need legal recognition and protection, and ICRAF has helped to negotiate legal status for them with the government.

Philippines

One of the main constraints on production in Southeast Asia is the extent of sloping land, with over half the land having more than 8 percent slope. "Conventional" agricultural practices contribute to soil erosion (60-200 tons per hectare per year) and ensuing fertility loss. For many years, farmers were advised (admonished) to construct terraces or to plant contour hedgerows to control erosion, but these technologies were not widely adopted, in part because of their high labor requirements.

In the Claveria region of northern Mindanao, there is now a simpler and cheaper technology developed by ICRAF and partners that is being widely adopted and adapted by farmers. It involves natural vegetative strips, with permanent ridge tillage, that are able to reduce soil loss almost completely. Maize yields have been increased from 1 to 2 tons per hectare to 2 to 3 tons, and research shows that the strips increase fertility over time. Some farmers are getting 12 tons of maize per hectare from two crops a year. The strips can be planted with fruit trees or other plants of economic value to further increase income.

Farmers estimate that the strips increase land values by 35 to 50 percent (Garrity 1999). It is very significant that

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[3]The main species in agroforests will naturally vary; examples include damar (for resin) in parts of Sumatra and jungle rubber in other parts of Indonesia; cacao in southern Cameroon; bolaina in Peru; and peach palm in Brazil.

farmers are now disseminating this technology by themselves. Over 100 farmer organizations with about 2,000 members have been formed around Claveria to promote the use of these natural vegetative strips. This is somewhat analogous to the LandCare movement in Australia. The groups undertake experimentation to evaluate alternative grasses or plants for use on the strips and establish nurseries for provision of planting materials. Local governments are now giving financial support to these organizations, which are spreading in Mindanao.

Requisites for Innovation

These examples of agricultural innovation rely on local ideas, resources and management as well as on scientific insight regarding natural resource management (NRM). The innovations are often stimulated by NGOs or international research institutions. Most exemplify NRM principles, and all are consistent with the insights coming from agroecological analysis.

The conference considered the potential that such innovations could have for meeting world food needs in the future. Our initial focus was on agricultural technologies and practices that have been devised and adapted, and on the yield increases that these could achieve, often under very marginal conditions.

What emerged from our consideration of the cases was an increased appreciation of the *processes* by which these innovations were evolved and diffused. In almost all the cases there was impressive social organization, whether formal or informal, which built on existing knowledge, roles, rules and incentives in rural communities, inventing new roles and relationships where needed.

The case studies gave repeated testimony to the productivity of farmer participation and leadership in these processes. This is not to say that all farmers in rural communities are avid innovators. Like other groups of human beings, there are many differences among farmers in their interests and talents.

But participants who had worked directly with farmers in these various programs provided many examples of situations where farmers improved on standard agricultural science approaches or generated new ideas altogether. Thus, we concluded that farmer-centered research and extension should not be a passing fashion in development projects, but a long-term strategy for improving agriculture in its many dimensions.

Less evident in the case studies were the larger political and economic forces that shape the evolution of agricultural systems in particular countries and local contexts. Most of the experiences reported had started in a particular region of a country or on a small scale, where they did not necessarily confront or challenge major powerholders.

Sometimes there was backing from an international research center or donor agency that made the work less vulnerable to resistance. The innovations were seldom being supported or favored by existing policies. But so long as they were enhancing productivity, conserving resources and benefiting rural communities, including their poorer members, the innovations have enjoyed considerable legitimacy and cooperation.

We cannot know what will be the results when there is strong opposition, possibly covert, to these new approaches. The IPM program in Indonesia was at one point threatened by commercial interests that had millions of dollars at stake from the import of chemical pesticides. In that case, however, there was strong political backing from the very highest levels of government, which helped inhibit opposition. Moreover, local government units contributed from their own budgets to promote IPM.

For the promising programs that are reported here to achieve national scope and impact, there will need to be supportive policies and institutional arrangements. The technologies will not spread by themselves, especially if they elicit resistance from powerful sectors because they provide alternatives to practices that are profitable for commercial interests, or if they empower and embolden rural people in some oppressive political systems. Policy research and reform will need to be an integral component of the innovation process.

To the extent that governments and donor agencies stand behind their pronouncements about ensuring food security, reducing poverty, and empowering citizens, it should be possible to establish and implement supportive policies. Getting such policies accepted and acted upon in the field by government professionals remains one of the greatest challenges. Many are doubtful that farmers (peasants, campesinos) can ever be very productive and therefore prefer to promote more capital-intensive development led by agribusiness enterprises. Refusal to accept the evidence of impressive grassroots agricultural innovation remains an obstacle to progressive rural change.

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Some of the agricultural reorientations reported here are already operating on fairly large scales and growing, such as integrated pest management in Indonesia (over one million farmers trained) and no-till agriculture in Brazil (400,000). Others are starting to scale up: the rice-fish farming program in Bangladesh will begin expanding to one million households next year, and tens of thousands of households are adopting agroforestry practices in central and southern Africa. In the Indonesian case, thousands of government staff have become trainers in IPM, having seen for themselves how much improvement in farmer practices is possible when a partnership relationship has been established. As very large numbers of farmers become involved in and benefit from agroecological agriculture, there will probably be more political support appearing at all levels for these changes to continue.

Transitions in Rural Areas

An objection raised by some critics is that farming systems that do not employ significant amounts of capital or chemicals lock rural households into small-scale agriculture for generations to come. Advocates of agricultural modernization think it a mark of progress for most households to leave the rural areas and make way for a process of land consolidation to occur, where agriculture becomes larger-scale, more mechanized and, they believe, more productive.

This conception of agriculture, however, ignores the fact that while larger farms may be more profitable for their owners, they are seldom more productive in terms of returns to land. Where land is the scarcest factor of production, increasing its productivity is a primary concern for society as a whole. Larger holdings are almost always farmed less intensively than smaller ones. In large holdings, when capital (mechanization) is substituted for labor, this lowers yields more often than it raises them.

Will the incomes from smallholdings be enough to satisfy people's aspirations as well as their needs? This is an important question. Small farms are already more productive per hectare throughout the world than are large farms, except when units are so small that households do not devote much attention or labor to them (Berry and Cline 1979; Johnson and Ruttan 1994). We have seen that intensification based on agroecological principles offers possibilities for substantially higher incomes: as much as ten times in a case in Kenya reported by Sanchez (1999). Where land is a limiting factor, smallholdings using labor-intensive technologies usually have larger returns to labor than big farms, where labor is employed extensively.

An urban lifestyle is not necessarily preferred by many people now living in rural areas. The higher incomes in urban areas are commonly matched by higher costs of living, with less satisfactory quality of life. The greater opportunities for public services, amenities and entertainment in urban areas are often associated with unpleasant crowding, crime and other undesirable conditions.

National development will include greater urban and non-agricultural development. Nobody should expect agriculture to employ indefinitely the same share of the labor force as it does now. Agroecology is not intended to keep rural residents "down on the farm," but to enable them to improve their livelihoods and especially their human resources so that they can have more desirable choices.

It is appropriate for governments and outside agencies to help increase the options that rural people have, for themselves and their children. They should not be confined to lives of rural poverty because of low productivity and diminishing natural resource quality. Nor should they be pushed by economic circumstances to migrate to urban areas due more to desperation than desire. There are many opportunities that rural agroindustries can create for adding value and income in rural areas, creating beneficial spread effects from agriculture. One example is the processing of damar resin in Sumatran villages in Indonesia. Another is the possible manufacture of medicines for prostate disorder from

Prunus africana in rural Kenya, Madagascar and Cameroon near where this rare but very valuable tree grows.

The kinds of agricultural improvements reported here, and still others that can be evolved by pursuing the same agroecological principles and similar participatory approaches, will strengthen the positions of rural people now marginal in economic, social and political terms. Once they are more productive, secure and confident, they can improve their rural environments further with the resources and organizational skills they have built up. Or they can make more successful lives in rural towns, regional centers or urban agglomerations if these appear more attractive.

Failure to promote people-centered agricultural and rural development of the kind reviewed here will accelerate migration to urban areas, in excess of the productive opportunities there that can utilize and support the population well. Experience reported from Bolivia indicates that while technologies conceived and developed externally may add to agricultural production, these contribute little to human development, which is needed for advances in all sectors. Farmers who have developed their analytical skills and their confidence from agricultural experimentation will be better able to be productive in cities if ever they are displaced to an urban environment.

Agroecology also is not wedded to using local resources exclusively. As seen in the Nigerian case presented, as population becomes more dense, it may not be possible to keep enough cattle for manure to maintain fields' fertility or to grow enough biomass for adequate compost. This makes

Where rural productivity is low, many young people are forced to migrate to urban areas to supplement the family income. By the age of 13, many of the girls from this Philippine upland village have left to work as domestics in Manila or Cebu City. Raising agricultural productivity and incomes in the countryside gives families more opportunities for work and education in their own communities, allowing them to maintain a rural lifestyle if they prefer.

use of chemical fertilizers necessary. Rock phosphate is an essential component of soil replenishment for phosphorus-deficient soils of Africa. While the replenishment of nitrogen can be handled well by agroforestry, phosphorus has to come from mineral sources.

In Madagascar, most farmers cannot afford fertilizer given their present low yields and income from rice. The system of rice intensification being introduced there can boost yields by several times. Sooner or later, it will be necessary to make inorganic soil amendments given the extremely low levels of phosphorus in most areas. Around Ranomafana National Park the level is 3-4 ppm in most areas and less than 10 ppm even in the best places. But if higher yields can be obtained for 5 to 10 years, farmers will be able to afford to buy fertilizers to maintain their soil fertility, which is critically dependent upon phosphorus availability.

Changing Roles and Practices

The conference reached the optimistic conclusion that small farmers in most parts of the less-developed world do not need to be food-deficit and as poor as they are today. Producers who could not benefit from capital- or chemical-intensive technologies because they were not suited to their conditions can profit from the knowledge-, skill- and management-intensive production methods of agroecologically informed agriculture.

Indeed, larger-scale farming units around the world can also benefit from understanding and adapting the principles and practices of such systems, as they are increasingly doing in the U.S. and Europe (Pretty 1998; Thrupp 1998). Most kinds of agriculture can become more productive and efficient by incorporating biodiversity, synergy and other aspects of well-functioning ecosystems.

Given suitable support, most smallholders should be able to feed their own households and communities and raise incomes significantly using these approaches combining agroecological and participatory principles. Moreover, a number of the technologies can increase production well beyond subsistence needs so that these households can contribute to national food security, including feeding growing urban populations, and even to exports of high-value products.

The potential to achieve this has been seen in the case studies considered. Whether this potential gets realized is uncertain, however, because this will depend on appropriate and greater investments, on supportive and consistent policies, and on rethinking what constitutes expertise.

The investments made thus far in alternative agricultural approaches have been minimal, a tiny fraction of the resources that have gone into mainstream agriculture. Most have been come from farmers themselves, augmented by resources for sympathetic research institutions, NGOs and universities.

Opportunities are being presently foregone to raise agricultural production in ways that are economically profitable, environmentally-positive, and socially uplifting. Directing policy and infrastructure investments more toward so-called “marginal” areas is justified by growing evidence that the marginal returns to investment there are higher on average than in the more advantaged areas, provided that the investments are not too scattered and sporadic (Hazel and Fan 2000).

It was suggested that rural communities be considered as a unit of scientific endeavor. Not all farmers are equally able or motivated to take leading roles in experimentation and evaluation. But those who have this talent and drive can motivate others to participate as positive results accumulate. There are a great many rural people who are as intelligent as the more educated personnel who work with them, and who can advance scientific understanding as well as apply it to achieving agricultural goals.

Grassroots scientific development should not be undertaken in isolation. The most successful examples, and those most able to have broader impacts, have been linked to NGOs, national and international research institutions, universities or government agencies. Such vertical linkages are important, but not more important than horizontal linkages among rural communities themselves, to exchange experience and encourage each other in this process. Farmer-to-farmer extension is possible as seen in our cases from Bolivia, Guatemala, Kenya, Malawi, the Philippines, Sri Lanka and Zambia.

Instead of the "linear" model of research and extension, where scientists develop new technology that is transmitted through extension workers to farmers, our experience and observations support the "triangular" model formulated by Merrill-Sands and colleagues (1990) for the International Service for National Agricultural Research (ISNAR). This envisions scientists, extensionists and farmers interacting with one another directly in a three-cornered relationship. Such collaborative efforts can be productive in many ways, as documented in Thrupp (1996, summarized in 1999).

Economic analysis, especially considering labor inputs, is important in such a process because for farmers, agronomic success is not enough. Labor in rural communities seldom if ever has zero opportunity cost. The slow spread of many practices that are agroecologically sound has often been due to their labor cost. Returns to labor in particular need to be assessed when evaluating possibilities for the adoption and spread of agroecological systems.

The conference reached the optimistic conclusion that small farmers in most parts of the less-developed world do not need to be food-deficit and as poor as they are today.

This accepted, conference participants added that economic profitability is not the only criterion affecting farmers' decisions. While income is important especially for the poor, it is not an exclusive concern. Risk is ever-present in rural environments, and it is always a reason for discounting prospective returns. Moreover, where markets are unreliable or difficult (expensive) to access, households will continue to regard self-sufficiency as the wisest strategy for food security, no matter what advantages may be attributed in principle to market participation.

Households also have cultural values that need to be respected, and most parents attach great importance to opportunities for the next generation. Maintaining intact and attractive rural communities is itself a value that is considered alongside individual increases in income. So, while economics need to be evaluated, because farmers want to know how innovations would affect their net income, it should not be considered as a sole determinant. This is only one of several tests that will be applied by farmers when assessing alternative agricultural practices.

Because the financial profitability of innovations depends upon access to markets that are remunerative, the development of markets and market access is particularly important. This may involve efforts as complex as removing monopsonistic controls and distortions, or simpler things like improving road networks. Access to credit is less crucial than when promoting more capital-intensive agriculture, because fewer external inputs need to be purchased, but it can be an accelerator of adoption and spread of new practices.

Security of tenure is important where agroecological agriculture requires investments of labor if not always money to raise the fertility and productivity of soil — by crop rotation, planting cover crops or green manures, using mulches or compost, terracing, water harvesting, etc. This does not always mean that farmers must have formal-legal title to land. But they must feel secure in their right to gain the product of their labor and to continue using the land that is being improved. This is an area of policy and institutional reform that should accompany any efforts to improve agriculture, agroecologically or otherwise.

Finally, this process of agricultural intensification will benefit from having functioning and supportive local government bodies and from a process of decentralization of government operation and powers more generally. In the Philippine case reported, with their authority and budgets now enhanced through decentralization, local governments are contributing to the spread of NVS farming systems. The IPM program in Indonesia got important boosts, when central government support sometimes flagged, from contributions to its expansion from provincial and district (*kabupaten*) governments.

In Bolivia, the use of leguminous green manures got started while the country was still highly centralized (one-quarter of the area did not even have nominal local government units). With decentralization after 1993, many of the local officials elected have been farmers or teachers involved with the World Neighbors program, bringing a high level of commitment and integrity to these positions as well as support for the spread of participatory agricultural development.

An overall conclusion documented in Thrupp (1996) is that these kinds of agricultural development can best be accelerated and guided by the creation of multiple and diverse *partnerships*. This has also been the experience in various country programs of CIIFAD (Uphoff 1996).

There has often been an assumption that partnerships are most successful when homogeneous. It may be true that “birds of a feather flock together,” but more benefit comes to farmers and more learning to other partners from having heterogeneous alliances or informal networks arrangements.

With a variety of partners working together on problem-solving and knowledge generation, ranging from communities to national government agencies and even beyond to institutions in other countries, there is a more diverse pool of experience and resources to be drawn on. Each partner can contribute to joint efforts according to its comparative advantage.

Spreading Innovation

It is often asked whether the small-scale successes achieved thus far along these new lines can be “scaled up” to become national programs. This question should be rephrased to avoid the implication that what is sought is "replication." This is inconsistent with the experience and philosophy of this approach.

More appropriate will be growing and spreading cumulative effects of an "aggregation" of individual and community efforts that are similarly motivated, but carefully evaluated and redesigned as necessary to meet local needs and situations. There can be widespread dissemination of technologies and practices in this way, provided that farmers and groups of farmers become engaged themselves in testing, evaluating and adapting options, rather than simply adopting them because they were told it would be good to do so.

For small and marginal farmers to contribute significantly to future world food production, institutional changes and investments are needed to realize this potential. These become more important as the processes of globalization in the economy and culture spread more widely. For farmers to be able to compete in larger markets and arenas, they must be able to "farm smart."

The changefulness of global opportunities and forces means that they have to be able to entertain many options and to make quick adaptations. Economic specialization becomes more appropriate as market access increases, but the logic of specialization should not necessarily be taken to its extreme because market forces are rapidly changing. Being locked in to a single mode of production or output can be economically fatal.

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Knowledge Needs

The process of transforming agricultural practices toward more agroecologically suitable ones remains challenging in part because of our insufficient knowledge. Yet the cases presented at the conference justify some optimism.

The concept of "syndromes of production" (Andow and Hidaka 1989) was considered useful because it recognizes the importance of synergy among practices. It also helps explain difficulties when trying to move from one "equilibrium" pattern of production to a more promising one. This problem can be understood in terms of "fitness peaks," where moving from one favorable position on the "terrain" of alternative combinations of practices may lead downhill into productivity "valleys" before reaching a greater "height" with some other combination (Power 1999).

In particular, there is still insufficient knowledge about soil processes and dynamics. Understanding the nature and outcomes of below-ground biodiversity was likened to "watching wrestling under a blanket." Yet soil is the foundation for all productivity in agriculture.

Because research into understanding the workings and integration of agroecosystems is unlikely to be a priority among farmers, this will be mostly the responsibility of scientists, though even such research should have farmer involvement. Areas for research in the agricultural realm where farmer participation will be greater include: nutrient cycling and application (Fernandes 1999); agroforestry (Sanchez 1999); aquaculture as an integrated component in farming systems (Brammett 1999); green manures, cover crops and improved fallows; composting and mulching; using biological means to control pests, diseases and weeds (Bunch 1999, Dessilles 1997, Jones 1997, and others); the contributions of animals to integrated farming systems (a presentation was made on this by Alice Pell); and land and water management, particularly including water harvesting and small-scale catchments (emphasized by Bunch from his experience in Central America).

In the socioeconomic realm, studies need to be done with farmers on the adoption and adaptation of agroecological technologies, as well as of "disadoption" where this occurs. There was evidence in the case studies of rapid and broad spread of some practices, but also instances of slow or halted adoption and even abandonment of others, e.g., the mucuna-maize intercropping system used in parts of Honduras (Neill and Lee 1999), and the farming system employing raised beds in Bolivia (Lines 1998; and Palacios 1999).

Other areas where knowledge is inadequate for supporting processes of farmer-centered research and extension most effectively are: What kinds of policies are most supporting or constraining for farmer initiative? What institutional requisites and impediments affect these processes? How can markets be developed most favorably for sustaining the development and extension of such processes?

Opportunities Foreseen

Two particular opportunities for institutional innovation were suggested. The first is to reorient existing agricultural extension systems and personnel to support participatory technology development and dissemination. This means moving away from top-down instruction of farmers to facilitation of learning by farmers, researchers and extensionists together. The other opportunity is to involve rural schools and school teachers in the processes of experimentation and evaluation, as this will reinforce parental participation and better prepare the next generation of farmer-experimenters.

This proposed approach to agricultural development, while drawing on existing knowledge and experience within farming communities, is thoroughly forward-looking. The synergistic principles of agroecology will help to circumvent some of the constraints that result from approaches heavily dependent on capital, chemicals and machinery, by capitalizing as much as possible on the power of biology, which can come at relatively low cost. Formal education and literacy are important but not in themselves sufficient. We are talking about knowledge-intensive forms of agriculture that transform rural people from their historical subordinated roles as "hewers of wood and drawers of water."

Three decades ago, when the Green Revolution was being launched, such high expectations for rural people were held by few persons outside of rural areas. It was considered that progressive change would not be initiated by farmers themselves. Yet the case studies presented at the conference give abundant evidence that the human capabilities available to be enlisted in a new kind of agricultural modernization have been underestimated and too narrowly conceived.

The technologies of the post-Green Revolution era will still require extensive contributions from scientists. However, technological development will proceed more effectively by walking on the two "legs" of agroecology and participation. The first encompasses all resources and aspects of living systems, while the latter draws in a multiplicity of roles and talents, emphasizing those of farmers as co-generators as well as users of new technology.

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