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# SOIL HEALTH: RESEARCH, PRACTICE AND POLICY FOR A MORE REGENERATIVE AGRICULTURE

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**Abstract:** Drawing on academic literature and personal experience, the authors highlight trends emerging from sustainable agriculture efforts in developing countries involving research institutions, action agencies, and communities to provide recommendations for advancing a soil health movement. They argue that multi-disciplinary and -institutional efforts on soil health that link research, practice, and political action will be needed for improved agriculture and more promising futures.

During this century soil research has concentrated on soil chemical and physical factors, with comparative neglect of biological factors. Consequently, there is relatively limited understanding of how best to capitalize on the dynamics and potentials of soil biology so as to enhance the regenerative capacity of soil systems for agriculture. More agronomic research and empirical experience for biologically-based agriculture are called for.

Although better understanding and practices can serve immediate on-farm needs, they alone would unlikely achieve the desirable changes in farming systems. Policies and institutional arrangements profoundly influence agricultural research and practice, so effective soil health initiatives must also engage broader social and political considerations. In particular, the author's argue for greater balance in research and teaching to emphasize biology and ecology, enhanced linkages between research and extension, new inter-institutional partnerships and collaboration, and increased stakeholder involvement in policy formulation and implementation.

Key words: soil health, regenerative agriculture, sustainable agriculture, agro-ecology, people-centered development

## AGRICULTURAL PROSPECT

*The issue is* how *growth should occur, not* whether *it should.*
Vosti and Reardon (1997)

Even though the rate of world population growth for the earth's six billion people has fortunately begun to decelerate, world food production by the middle of the next century will probably need to be at least double the present level (FAOSTAT, 1998). By then, the total

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human population needing food will likely be between nine and ten billion people. In addition, we must reckon with: (a) rising demand for food due to further growth of incomes; (b) shifts in diet to more animal-based consumption that will require more total agricultural production to achieve the same nutritional values; and (c) a large backlog of unmet requirements for food (Conway 1997). We should never forget that today about 800 million persons, or about 13 percent of the planet's population, are severely undernourished.

Certainly the Green Revolution, which combined biological (chiefly genetic) improvements with the application of non-biological inputs (chemical fertilizers, agrochemicals, and irrigation water), made impressive contributions to food production over the past three decades (Conway, 1997). The world would have faced major food shortfalls without the yield increases it brought. But its gains are now diminishing as shown by declines in marginal productivity of agricultural inputs. For example, worldwide rate of increase in cereal production, having been 2.4 percent in the 1970s and 2 percent in the 1980s, has been less than 1 percent in the 1990s (FAOSTAT, 1998).

Moreover, critics have raised valid ecological and social concerns over agriculture that depends heavily on external inputs, in particular if it is dependent on finite fossil fuel reserves. As Conway (1997) argues, not only must the next Green Revolution produce more food, wood, and fiber than the first, but it must also be more "green," in that its methods need to be increasingly conservation effective. Its outputs must be nutritionally beneficial and affordable for our poorest people, who often survive in very fragile environments and under highly difficult economic, social and political conditions.

Given that both land and water resources are limited and increasingly scarce, most of the growth in food production will have to come from productivity gains. The additional land that can be brought into production is generally of lower quality and at greater risk of degradation than that presently cultivated (de Graff, 1996; Oldeman et al., 1991). Also, we continue to lose some of our best agricultural land each year due to erosion, salinization, urban expansion and other factors. Furthermore, there will be more competing uses for the limited quantity of fresh water available on earth, and, as in the case of soil, there will be continuing declines in resource quality. So production gains will have to be made on a relatively smaller and rather vulnerable natural resource base. Both intensification and sustainability must be imperatives for the future.

## SOIL HEALTH FOR A MORE REGENERATIVE AGRICULTURE

*One of the last great frontiers in biological and ecological research is the soil.*
Coleman and Crossley (1996)

Fortunately, continuing knowledge and technological advances are likely, but today we need to ask ourselves: in what direction should agricultural research and practice go? The authors propose here that a substantial share of future efforts should strive to better maintain and improve the regenerative capacity of our production systems and in particular the quality of soil functioning, that we refer to as sustaining and enhancing *soil health*.

As Shaxson (1997) has argued, the challenge facing the world's scientists, policy-makers and particularly its farmers is to find ways to continue to produce more food on relatively less land, where there will be less opportunity for land recuperation fallow periods, more net loss of nutrients and more build-up of crop pests and plant pathogen populations. Land productivity will increasingly depend upon soil amendments and on intensive management measures to control pest populations.

Built on biological principles, regenerative agriculture seeks to concurrently enhance productivity and environmental management (Pretty, 1995). According to Pretty, who studied a broad range of rural development initiatives in Africa, Asia, and Latin America, "There is now strong evidence that regenerative and resource conserving technologies and practices can bring both environmental and economic benefits to farmers, communities, and nations." With concern to soil management, a regenerative approach would center on the management of biological means to enhancing fertility for increasingly productive and sustainable agriculture.

The movement among academics and practitioners to call attention to "soil health" has emerged as result of a convergence of new appreciations and catch up with farmers' long standing questions and concerns. The Soil Science Society of America and the Rodale Institute have made concerted efforts to reach consensus among agricultural scientists on the meaning of *soil quality,* a term closely related to, but more specifiable than, soil health. According to Doran and Parkin (1994), soil quality is "The capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health." According to Harris and Bezdicek (1994): "The terms *soil quality* and *soil health* are currently used interchangeably in scientific literature and popular press. In general, scientists prefer the term soil quality and farmers prefer soil health." The terms can be analytically differentiated by associating "soil health" with holistic soil management, while using "soil quality" to describe the constituent parts of soil -- i.e., its biological, chemical, and physical characteristics. Because the latter view is more static, the authors favor "soil health" as a concept.

Downes (1982) has written: "In the natural state, land has a dynamic equilibrium. The trend of the interactions and the resulting succession of different species of plants and animals is towards a maximum sustainable biological productivity attainable from the available array of species." People alter natural systems, however, because the existing maximum biological productivity is either insufficient or undesirable. Some soils are quite accommodating to human interventions while others have low tolerance. Consequently, we need to apply ecological principles to devise suitable and stable systems of management for different kinds of land. This requires more than knowing the physical and chemical properties of the soil; there must be an understanding of soil ecology and of the obstacles to be overcome to achieve and maintain effective, dynamic balances.

An important but often overlooked characteristic of soil, thus far primarily assessed in terms of present productivity, is its overall resilience, often referred to as *buffering capacity.* Farming systems must constantly deal with stress, so buffering capacity is essential for assuring food security and stable livelihood. Bezdicek et al. (1996) delineate several important effects of buffering: the ability of a soil to remain productive in spite of stresses such as scarcity or abundance of water, disturbances such as tillage, or imbalances such as those caused by pest outbreaks. While certain chemical and physical qualities are conducive to resilience, studies argue that the actual restoration and maintenance of soil quality depends primarily on biological activity (Abawi and Thurston, 1994; Bezdicek et al., 1996; Coleman and Crossley, 1996).

There is growing concern with the impact of agricultural and other land use practices -- tillage, pesticide use, cropping schemes -- on soil ecology. Thurston (1992) has written of many ways in which our contemporary agriculture has been creating pest problems. Cultivation, cropping and other management practices all place selection pressure on particular organisms. Promoting certain organisms will inhibit others. While our knowledge of biological processes is still limited, we are not yet taking much advantage of what we already know about agro-ecologically sound soil management.

## AGRONOMIC APPROACHES TO SOIL HEALTH

Much of the literature on soil management and associated policies have focused on physical soil erosion. Although erosion can be an important component of soil conservation, in most cases this preoccupation could be characterized as an approach based on "locking the stable door after the horse has been stolen.”

As Shaxson et al. (1997) have appropriately argued, "Yields after erosion are related less to the quantities of soil removed than to the fertility of the soil that remains behind." Rather than fixate attention on soil *loss*, we should direct our thinking toward better management of *existing* soils, which is largely accomplished through managing the soil's surface and its physical covering, usually through the management of plant populations. Moreover, effective soil management, maintaining healthy soils, can have desirable preventative effects on soil loss.

Although much research still needs to be conducted and evaluated to have a full understanding, the soil management literature is progressing toward consensus on interacting conditions for achieving better soil health through management (Box 1). Many of these conditions for more regenerative agriculture have been known for a long time to be beneficial, but our approach to soil has been mechanical -- manipulate it -- rather than biological -- nurture it. We have put prescribed nutrients into the soil in order to extract desired products, rather than apply principles that will sustain and multiply the soil's own productive and recuperative capacities.

## PRIORITIES FOR SOIL HEALTH

The reorientation of agriculture toward strategies that are basically more regenerative than extractive is still gaining momentum, and the result will likely be some hybrid approach rather than a simple replacement of present farming. For long-standing progress in soil health, the authors see emphasis by scientists particularly needed in three areas: correcting research bias and addressing knowledge needs, adopting more farmer-centered approaches, and greater collaboration and policy intervention.

### Research Bias and Knowledge Needs

The Green Revolution technologies, utilizing new improved seed varieties and other purchased inputs, were fairly widely adopted, but only under certain conditions where they performed well (Conway, 1997; Uphoff and Fernandes, 1998). The effectiveness of varieties and associated technologies depended on site-specific research across many and varied environments. This realization underscores that scientists are dealing with biological rather than mechanical processes when it comes to getting plants (and animals) to grow better.

Such understanding is likewise needed for better soil management.

Taking into consideration the totality of soil research conducted during the past century, the authors would estimate that 90 percent dealt with chemical or physical aspects, with less than 10 percent devoted to better understanding of soil biology (informal survey among soil scientist colleagues). Further, we estimate that at least 90 percent of plant research has focused on above-ground parts and functioning, and probably less than 10 percent on roots and their below-ground interactions.

This disproportionate and self-evidently suboptimal allocation of research resources is easily explainable. It is generally much easier to study and quantify soil chemistry and physics than soil biology (Campbell, 1994). There are quicker results, and such research appears more scientific for being more precise and less ambiguous than the complex realm of biology. Soil chemical and physical research has produced agricultural innovations such as synthetic fertilizers and machinery that are easier to develop and utilize than potential biological "products". As Campbell (1994) has contended, “One of the problems with these [biologically-centered] systems of controls is that there is usually no patentable or marketable product, and therefore no commercial interest and few research funds.”

Nevertheless, our food security and our futures should not be determined by the ease or profitability of research. There are *prima facie* reasons to expect that future research on soil biology and below-ground processes would generate valuable new knowledge, if only because less work has been done in that area. Moreover, recent experience has shown that the application of biological concepts, such as diversity, dynamics and synergy, can help to maintain the ecological integrity of farming systems and assure greater production security and longevity (Lal, 1991; Thurston, 1992). Research efforts that regard soil more in terms of four dimensions than two, as something living rather than inert, and as a body in constant change over time, should open up new opportunities for improving agriculture.

The Cornell International Institute for Food, Agriculture and Development (CIIFAD) has participated in regional initiatives to promote such thinking on soils. During a Central American workshop we asked farmers, extensionists, and scientists to outline their information and knowledge priorities (Box 2). The participants called for research to determine useful soil health indicators and the impact of practices on specific organism populations and overall soil buffering capacity.

Rather than concentrate resources to produce a growing supply of research results as the driving force behind agricultural change, we also need to create conditions for more demand-driven research, where scientists play more interactive and responsive roles, not insisting on their own control of the process and unilateral decision-making (Selener, 1997). We also have much to gain from extracting further utility from what we already know. The recent popularity of limited tillage and cover crops demonstrates that alternative perceptions, interpretations, and applications of “old ideas” can lead to new farming advances, even without further research investments (Buckles et al. 1998, Cagliari et al. 1993, Monegat 1991, Thurston 1996).

Research is needed to determine the relationships between soil health and farming productivity and sustainability. Sustainability itself is still a very ambiguous and difficult term to operationalize. There is an unavoidable problem that sustainability cannot be validated or proven in the present, but only in the future. This said, it is still possible to critique and discard some practices as inimical to sustainability, thereby narrowing the range of what remains to be considered.

For example, there is need for a better understanding of the consequences and management of *biodiversity* within soil systems. Coleman and Crossley (1996) remind us that the natural environment is infinitely complex, and every agricultural "solution" leads to new problems. Despite this complexity, nature is not chaotic and entirely unpredictable. They argue that on the contrary, populations of soil organisms tend to reach dynamic equilibria within and among species. We see from farming and from scientific experimentation that the environment follows its own logic that is interpretable and therefore manageable. We should strive therefore to discern and understand the biological, physical, and social principles behind effective agriculture, those ideas and actions that agree with and strengthen the dynamics and integrity of natural and managed ecologies, while also contributing to production needs.

The soil research literature is replete with well-validated research designs for examining and controlling abiotic factors. We should have comparable designs and methodologies for biotic factors, recognizing that the latter will be at least an order of magnitude more complex and demanding. We have already many tools that can assess microflora and fauna (e.g., Cadisch and Ehaliotis 1996), but tracing links among kinds of organisms and showing their consequences for the overall health and productivity of soil systems will be very demanding.

We need to apply such methodologies to better understand the impact of specific agricultural practices, such as organic amendments, rotations, tillage and pesticide use, on soil regenerative capacity, in order to help farmers identify opportunities for improving their production systems. Rather than be preoccupied with finding single-element solutions, we should design broader strategies that apply multiple tactics and demonstrate an understanding of the ecological principles, such as the concept of abundance and diversity.

**Farmer-centered Approaches**

*The direction at the crossroads is clear: when the untapped potentials of the land's living resources combine with the latent skills and enthusiasm of rural people, better husbandry of land in the tropics becomes a reality.* Shaxson (1997)

Popular change paradigms were effectively built on the argument that the best way to raise agricultural output was to equip scientists with research facilities and assign them the task of devising useful solutions to farmers' problems. Extension programs then induced or pressed farmers to accept these ideas based on others' understanding of local needs, interests and capabilities. The World Bank's Training and Visit system is a case in point (Benor et al., 1984). The result has been limited adoption of most externally generated practices. Doing "more of the same" in agricultural research and extension is thus no longer a promising strategy.

Recently a group of Honduran farmer leaders met with a group of 40 representatives from diverse development organizations to present lessons-learned 15 years after their participation in the highly acclaimed Güinope Integrated Development Project, that emphasized soil conservation (Larrea and Sherwood, 1999). Their comments, summarized in Table 1, emphasized the importance of designing projects that contributed to more genuine local empowerment, meaning that rather than be passive beneficiaries, communities should ultimately direct their own change.

In response to limitations in technology- or content-centered approaches to change, beginning in the 1980s rural development theory and practice began to adopt more people- and process-centered approaches (Bunch, 1982; Chambers, 1983; Chambers et al., 1990). Instead of viewing farmers as recipients or adopters, rural development experience overwhelmingly demonstrates economic and social advantages to helping farmers become partners in linked discovery and action processes directed at solving problems (Bunch, 1982; Bentley and Andrews, 1996; Hamilton, 1997; Krishna and Bunch, 1997 ; Selener, 1997; Ooi, 1998).

The farmer-centered approach is built on the belief that farmer need themselves to be continually assessing and innovating with methods rather than being at the receiving end of a technology transfer process that cannot be current and quick enough to keep pace with changes at farm level. In addressing the demands of soil integrated nutrient management (INM), Deugd et al. (1998) compare the "transfer of technology" and "facilitating learning" praxeologies and argue that INM efforts should center on "facilitating learning" (Table 2). The new paradigm implies inducing innovation by giving farmers greater control over the research agenda and its implementation and emphasizes the process of learning over the teaching of content.

Selener (1997) draws on over 1,200 sources in describing the evolution of the increasing role of farmers in learning and teaching processes, demonstrating that we have made much methodological progress in the last thirty years. Nevertheless, he provides examples of qualitative differences in the design and implementation of such methodologies and expresses particular concern over continued scientist domination over decision-making processes. Drawing on lessons from participatory rural appraisals and participatory technology development, Deugd et al. (1998) and Defoer et al. (1998) provide examples that illustrate how marrying participatory action research with quantitative methods can contribute to more effective soil management planning, experimentation, and practice. Similar approaches to bringing together farmers and scientists to better understand soil biology and its management would be a useful methodology for advancing the ends of soil health.

**Institutional Collaboration and Policy Intervention**

Axinn and Herisse (1996) view institutional accountability to intended beneficiaries as a "hallmark of effective development work." They also acknowledge that genuine collaboration has very high transaction costs, but point out, "those costs are a necessary investment for successful development activities." We agree.

Outsiders have led most institutional contributions to change via time limited and thematic special projects, focusing on such topics as soil conservation or integrated pest management. Chambers (1983) describes "outsiders" as those people concerned about rural poverty, but who are not rural or poor themselves. They are usually wealthy, well-educated, and urban-based. Intentions aside, their view of poverty is often shaped by physical, cultural, and economic distance that distorts their understanding of the rural situation. Since the early 1980's, there has been growing dissatisfaction with this mode of operation (Chambers 1983, LeComte 1986, Kaimowitz 1994). Whereas special projects were credited for professional expertise, innovative approaches, and flexible organization, they were criticized for limited coverage, short-term mindset and emphasis on outside, rather than community priorities.

They also usually permitted only limited beneficiary participation and control over resources, which led to problems of accountability and relevance.

In the 1990's, donors began to look for alternative development strategies. As David Korten (1980) argued in his seminal paper, development efforts were more likely to be successful if organizations used a dynamic "learning-process" approach to implementation. CIIFAD has found that in order to be effective over the long-haul, diverse stakeholders, such as development organizations, communities and universities, must lead and manage development efforts collectively and through collaborative mechanisms (Uphoff, 1996).

Approaches to technology development that involve the technology users from the start of the process, not as recipients at the end of it, will require cooperation among scientists, extensionists and farmers but also among different kinds of institutions. Collaborative approaches that bring together diverse perspectives and abilities can provide new opportunities and returns for sustainable agriculture (Uphoff 1996). However, such initiatives make new demands on institutional arrangements, requiring innovative changes to administrative structures and management mechanisms (Fisher et al. 1998; Sherwood and Chenier 1998).

By its nature, concern with soil health focuses at the "grassroots." We seek investments, incentives, and other favorable conditions that can influence farming practice that will take advantage of the biological potentials of soil systems for sustainable production. But many of the influences on that behavior originate at higher levels, far removed from the field. Thus, efforts to improve soil health need to encompass more "macro" issues, recognizing that farmers, like the rest of us, live in a world of external influences and continuous change. The importance of taking on political concerns can be seen from the experience on the northern coast of Honduras, where innovations that conserved and enriched soil to support smallholder production in the 1970s and 1980s became less attractive in the 1990s, due to changes in external conditions (Box 3).

External conditions, such as economic, social and political forces, can overwhelm farmers and override the immediate benefits and advantages of better soil management. It makes no sense simply to stick with a research agenda on farming systems improvement through soil health promotion, without addressing in a serious and active way the external factors that ultimately shape agricultural practice via farm families' decision-making.

The globalization of commodity markets is a reality; the success of domestic economic policies will depend on our ability to facilitate both economic and social progress that conserve the resource base. We need to consider more seriously how developments in the broader economic and social policies can contribute to more favorable conditions for sustained rural progress, and particularly for agriculture and soil management. As Pretty (1995) emphasizes, not only do we need useful technologies to manage information and environmental resources; we must also create new opportunities for learning and innovation; more accessible and beneficial markets (both local and external); equitable and assured access to land and water resources; and appropriate, well-enforced laws and policies that assure reasonable equity within the farming sector.

## RECOMMENDATIONS FOR SOIL HEALTH

Concern about soil health is motivated by both present and future interests. It can contribute immediately to agricultural productivity and profitability, and at the same time, it is essential for the long-term maintenance of both productivity and profitability. It has the advantage of harnessing the power of biology for human benefit if we can learn better how to work with the dynamics of nature rather than trying to force nature into our arbitrary constructions.

In summary, we list a number of recommendations emerging from the experience of CIIFAD and its partners institutions and colleagues that can support soil health initiatives:

**Research**

- Restore balance in the agricultural research agenda. Compensate for past neglect of and under-investment in the realm of soil biology, with special emphasis on sub-surface components and processes.

- Begin with what we know. Build on existing scientific knowledge and methods, to expand efforts into the biological realm. Some of the tools of the Green Revolution will be relevant. Many of the concepts and methodologies developed for more interactive, holistic agriculture, such as integrated pest and crop management, will be helpful.

- Reform our thinking and teaching. Many of the limitations we confront are cognitive and mental, more than material or ideological. We need to think differently about agriculture, in particular moving away from the mechanistic approaches that relied most heavily on engineering, chemistry and "redesigning" plants through genetic manipulations, and instead trying to capitalize upon genetic potentials that already exist within complex ecosystems (Uphoff and Fernandes, 1998).

**Approaches**

- Engage farmers as partners in improving soil health. We see the challenge not as that of *changing* farmers but of *engaging* them in processes of identifying and prioritizing problems and opportunities, testing and evaluating innovations, and then helping to disseminate these in a process of participatory learning and technology development (Bunch, 1982; Chambers et al., 1990; Scoones and Thompson, 1994; Ooi, 1998).

- Link research and extension in tandem, rather than in sequence. Move away from the "linear" model of agricultural research and development where scientists devise technologies that extension agents in turn demonstrate to farmers, who are expected to adopt them as "packages". The "triangular" model that the International Service for National Agricultural Research (ISNAR) has proposed (Merrill-Sands and Kaimowitz, 1990) makes more sense, with researchers, extensionists and farmers all working together to create and spread better practices and methods, optimizing rather than maximizing the present "divisions of labor."

- Strengthen capacities. Re-invest present funds directed at technology transfer to enabling a variety of institutions -- government, non-governmental, grassroots -- from local to national levels to create networks of communication and cooperation. They need enhanced human resources working in participatory, experimental modes to raise awareness and accomplish behavioral changes that improve soil health.

**Collaboration and Policy Intervention**

- Foster inter-institutional partnerships and collaboration. CIIFAD has been finding *collaborations* to be very productive as an organizational alternative to "projects" (Sherwood and Chenier, 1998; Uphoff, 1996). Collaborations bring central government, NGO, and university partners together with community and local government representatives, also bringing in the private sector where possible, to deal with problems that are mutually identified and comprehended. Solutions are arrived at with each partner contributing according to its comparative advantage.

· Influence policy for sustainability. The preceding steps all seem easier than this last one, so it is often ignored or left to others. The political arena demands the expertise of scientists and the practical orientation of farmers. Rather than planning from above and imposing coercive punitive measures on farmers, we need to find effective ways of involving multiple parties in dialogue and policy formulation processes, such as through public focus groups and applying participatory methodologies (Lee, 1993; Röling, 1996; Scoones and Toulmin, 1998). We do not have any substantial power base to work from, but we can mobilize expertise and knowledge of the future consequences of policy alternatives and have a critical impact on decision-makers' thinking and policy outcomes.

The knowledge- and management-intensive requirements of soil health demand linking up of scientists and practitioners. A first step toward meaningful change is that of raising awareness among persons in key positions of the need for better stewardship and enhancement of soil resources. Beyond this, we need to inspire many people to act upon our understanding and continual lessons. Progress will demand not only multidisciplinary thinking and effective integration of multiple perspectives both in the laboratory and the field, but also effective collaborative action that lead to policies for more regenerative agriculture and more promising futures.

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**Box 1. Promising agronomic approaches for achieving soil health**

Soil Cover -- For regulation of soil temperature, for protection of the soil surface, and for healthy surface biological processes (Cagliari et al., 1993; Thurston et al., 1994; Thurston, 1996; Triomphe, 1996).

Soil Structure -- Soils are like buildings, Shaxson (1996) suggests, with the most important activity occurring inside the structures and between them, i.e., in spaces. This is where there is water flow, gas exchange, animal and plant movement, and other activities that are essential for agricultural production.

Diverse Biology -- For ecosystem resilience and vigor and to benefit from biological and other buffering capacities (Abawi and Thurston, 1994; Kennedy and Smith, 1995).

Nutrient Amendments -- As necessary to replace nutrients lost from the soil system by harvest of plants, by leaching, and by unavoidable runoff. This can be achieved by adding organic or inorganic materials to the soil, though there are advantages from the former that go beyond nutrient replacement (Abawi and Thurston, 1994).

High Soil Organic Matter (SOM) Content-- We are seeing a revival of interest in SOM, especially as there is more evidence that the presence and use of organic materials makes nutrient cycling and the addition of chemical fertilizer more beneficial (e.g., Schlather, 1998). The challenge is how to substantially increase and maintain organic matter in large cropping areas and use chemical fertilizers optimally.

Varying Use and Recuperative Periods -- We need to understand better how the management and intensification of fallows can help renew and strengthen positive biological, chemical and physical soil components for continued crop growth. These capacities are strongly dependent on the presence and types of organic matter and the activity of micro-organisms (Coleman and Crossley, 1996). Plants purposefully grown on and in the soil during "fallow" periods between cropping cycles can contribute to both. Experiences from Southern Brazil, Argentina, and Paraguay, where state extension services have disseminated and evaluated crop rotations and fallow management on a large scale, are showing the value of diversity in soil uses and that what happens during non-cropping periods can be more important for sustaining soil health than activities associated with cropping (Monegat, 1991; Cagliari et al., 1993).

Limited Tillage -- While some disturbance of the soil contributes to its aeration (an important factor in plant growth) and can alter the balance of flora and fauna in desired directions, it often exposes the soil and its biological elements to diminution. Accordingly, limited till or no-till practices, in which all or much of the SOM is retained on the soil surface, are gaining acceptance and popularity as means to maintain and even enhance soil fertility (Monegat, 1991; Cagliari et al., 1993; Thurston et al., 1994; Thurston, 1996; Buckles et al., 1998).

**Box 2. Central American Collaborative Initiative on Soil Health**

In 1996, Cornell University and the Pan American School of Agriculture in Honduras (Zamorano) initiated an effort to bring farmers and experts from the fields of entomology, agricultural extension, microbiology, nematology, plant pathology, and soil science together to generate a dialogue around their different perspectives. Individuals from multiple institutions, including the Centro Internacional de Agricultura Tropical (CIAT), Centro Internacional de Documentación sobre Cultivos de Cobertura (CIDICCO), the Fundación Hondureña de Investigación Agrícola (FHIA), the Natural Resources Institute (U.K), the Silsoe Research Institute (U.K.), and the University of Florida, have participated in this effort. The goal has been to build new awareness of the processes involved in maintaining soil health, especially regarding the abundance, diversity, and ecology of soil organisms and to explore more optimal management of agricultural practices.

In November of 1997, 27 researchers, extensionists, and farmers working in Central America convened at Zamorano for five days to learn about soil health, to share experiences, and to assess needs for the future. During the workshop, experts from diverse backgrounds contributed instruction and participants conducted soil analysis in the field and in laboratories to learn about how specific practices affected organism diversity and abundance. During the last day, the group discussed learning and research needs. Specific outputs were (from unpublished workshop proceedings):

Farmers' perspective:
"We need training on the role of soil organisms and information on the impacts that our practices have on them."

Messages needing to arrive to farmers:
- The soil is alive.
- Our practices affect soil organism populations and can create pest and disease problems or prevent them.
- Organically-based agriculture tends to impact the soil more favorably than conventional, chemically-based agriculture.

Researchers' perspective:
"We need to determine effective indicators of soil health and develop appropriate research methodologies. We then need to apply those methods to understand how alternative practices effect soil health and agricultural production to outline new guidelines for a sustainable agriculture that centers on good management of soil organisms."

Research demands:
- "Best" research methods (simple but useful indicators and practical means of measurements (e.g., bioassays).
- Understanding of how different farming practices (rotations, green manures, tillage, pesticides) interact and affect indicators in distinct ecological zones and farming systems.
- Evaluate alternative organic amendments (especially green manures and cover crops)
- Establish mechanisms of collaboration between researchers and farmers.

**Table 1. Synthesis of key principles and effective strategies of farmer leaders and development organization representatives for achieving more effective rural development (Larrea and Sherwood, 1999)**

| Principles | Strategies |
|---|---|
| Increasing participation | • Begin with local priorities.<br>• Be inclusive (include women and the other disadvantaged).<br>• Work with local knowledge and available resources.<br>• Increase involvement of local actors in decision-making and ultimately permit community control over projects |
| Avoidance of paternalism | • Avoid using external incentives (e.g., gifts and subsidies) to motivate participation.<br>• Use success as a strategy to inspire increasing involvement and participation. |
| Integrated human development/people center | • Attend to the "Human farm" (development of knowledge, skills, and motivations).<br>• Technologies should be seen as tools. The adoption of technologies should not be seen as an end in itself. |
| Community-oriented, flexible projects | • Respond, do not lead.<br>• Develop projects and methodologies in collaboration with communities.<br>• Grow with the changing needs, interest, and abilities of intended beneficiaries. |
| Collaboration with multiple institutions | • Involve the range of local organizations and develop abilities to work together.<br>• Build linkages among multiple development organizations and coordinate efforts. |
| Start small | • Begin with small, manageable projects that permit people to build confidence and abilities without involving them in substantial risk. |
| Quality agents of change (extensionists and promoters) | • Practical experience with farming.<br>• Competent with agriculture, teaching, and organizing.<br>• Aware and genuinely sensitive to the local situation. |
| Local leadership and innovation | • Enable local leadership and achieve change through leaders.<br>• Chose leaders who:<br>- have thirst and ability for learning.<br>- have successfully applied innovations to farms.<br>- demonstrate volunteer spirit.<br>• Promote democratic (rather than autocratic) leadership styles.<br>• Promote independent learning (experimentation, analytical skills, and self-discovery). |
| Local initiative | • Encourage communities to generate projects and provide organizational support.<br>• Facilitate information, didactic materials, and logistical support. |

**Table 2. Matrix showing different praxeologies underpinning innovation in agriculture (Deugd et al., 1998)**

| | Transfer of technology | Facilitating learning |
|---|---|---|
| Farm practices | Utilizing science-based uniform component technologies | Running the farm as a sustainable agro-ecosystem |
| Farmer learning | Adoption | Becoming expert at observation, inference, anticipation, and applying principles (usually in learning groups) |
| Facilitation | Transfer (demonstration) | Participatory non-formal education based on discovery and experiential learning |
| Support institutions | Institutions 'calibrated on science-practice continuum' | Decentralized learning network of trained farmers and trainers |
| Conducive policies | Subsidies on fertilizers and pesticides, high investment in research and extension | Prohibitions of pesticides, levies on nutrient emissions, protection of green labels, removal of subsidies on chemicals |

**Box 3. Abandonment and dis-adoption of the highly productive and resource conserving maize-mucuna cropping system on the Honduran north coast**

Since the mid-1980s, a number of development organizations and research institutions, including the International Clearinghouse on Covercrops (CIDICCO), the International Center on Tropical Agriculture (CIAT), the International Center on the Improvement of Maize and Wheat (CIMMYT), Cornell University, and North Carolina State University, have studied the traditional maize-velvetbean (*Mucuna* spp.) cropping system on the Honduran north coast. The system is impressive for simultaneously increasing production while decreasing labor demands and conserving the natural resource base, both saving and enriching soil -- extraordinary achievements (Buckles et al., 1998).

By intercropping mucuna with maize, farmers were able to double the average yields of the maize crop grown after planting mucuna, while also maintaining soil nitrogen and actually increasing organic matter content in the soil (Triomphe 1996). Yet despite widespread adoption in preceding years of a system that appeared to be highly productive, sustainable and socially equitable, many farmers have now begun to abandon agriculture and, accordingly, the maize-mucuna system (Humphries, 1997; Neil, 1998).

In the last five years, economic restructuring policies of the Honduran government and other external factors have contributed to significant concentration of land ownership and monopsony control over markets, and have thereby widened the gulf between social classes in the countryside (de Fontenay, 1997; Humphries, 1997). This has led to migration to other rural areas as well as to urban centers. Irresponsible land use by farmers as well as agro-industries has contributed to alarming destruction to forest, water, and soil resources, and indirectly to greater urban squalor. This case demonstrates the enormous need for research institutions and development organizations to address policy considerations and influence decision-making in ways that are more consistent with regenerative agriculture goals.