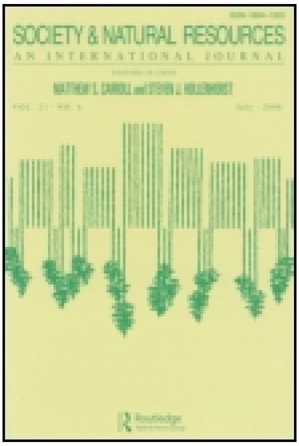


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# Agroecology versus input substitution: A fundamental contradiction of sustainable agriculture

Peter M. Rosset [a] & Miguel A. Altieri [b]
[a] Institute for Food and Development Policy (Food First), 398 60th Street, Oakland, California, 94618, USA E-mail:
[b] Department of Environmental Science, Policy and Management, University of California, Berkeley, Berkeley, California, USA

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# Agroecology versus Input Substitution: A Fundamental Contradiction of Sustainable Agriculture

PETER M. ROSSET

Institute for Food and Development Policy (Food First)
Oakland, California, USA

MIGUEL A. ALTIERI

Department of Environmental Science, Policy and Management
University of California, Berkeley
Berkeley, California, USA



*The central question posed by this essay is whether sustainable agriculture will be able to rescue modern industrial agriculture from its present state of crisis. To answer this question this article begins by outlining the economic, social, and ecological dimensions of the crisis, each of which must be addressed by an alternative paradigm in order to pull agriculture out of crisis. It then examines a persistent contradiction in the alternative agriculture movement: that of input substitution versus agroecologically informed transformation of farming systems. It is argued that the prevalence of input substitution, which emphasizes alternatives to agrochemical inputs without challenging the monoculture structure of agricultural systems, greatly diminishes the potential of sustainable agriculture. By only addressing environmental concerns, this dominant approach offers little hope of either reversing the rapid degradation of the resource base for future production or of resolving the current profit squeeze and debt trap in which the world's farmers are caught.*

**Keywords** agroecology, alternative agriculture, farm crisis, input substitution, organic farming, sustainable agriculture

## Sustainable Agriculture and the Farm Crisis

The central question posed by this essay is whether sustainable agriculture will be able to rescue both First and Third World farmers from the enduring crisis of "modern" industrial or Green Revolution–style farming. To answer this question, we begin by outlining the economic, social, and ecological dimensions of the crisis, each of which must be addressed by an alternative paradigm so as to pull agriculture out of crisis. We then examine the concept of sustainable agriculture in the light of these dimensions and find a persistent contradiction, namely the dominance of an input substitution discourse in which agribusiness has appropriated the concept of sustainability to its own ends. We argue that the prevalence of input substitution greatly diminishes the potential of sustainable agri-

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Address correspondence to Peter M. Rosset, Institute for Food and Development Policy, 398 60th Street, Oakland, CA 94618, USA. E-mail: rosset@violet.berkeley.edu



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culture to address successfully the root causes of the socioeconomic and ecological crisis facing modern farming. The input substitution approach only emphasizes environmentally benign alternatives to agrochemical inputs, without challenging either the monoculture structure or the dependence on off-farm inputs that characterize agricultural systems.

## Economic and Social Dimensions of the Crisis

Although the crisis of modern agriculture is universal, encompassing both developed and Third World economies, it is useful to begin with the United States, arguably the birthplace of industrial farming. Figure 1 shows the steep decline in the numbers of farms in the United States during the postwar period, the first indication of crisis. It should be abundantly clear that 3 million farmers went out of business for economic reasons, not for primarily environmental ones; therefore alternatives that tinker with the ecological side of the equation without touching the economic side are doomed to failure. The reality is that U.S. farmers have increasingly been caught in a cost–price squeeze whereby the ballooning costs of modern farm technology have consistently swallowed any increases in farm income, as shown in Figure 2.

Whereas food prices have long been stagnant because of overproduction, costs of manufactured inputs have soared (Wessel and Hantman 1983; Strange 1988; NRC 1989; Krebs 1991; Guither, Baumes, and Meyers 1994). Farmers have been driven into debt to cover the costs of $40,000 tractors and $100,000 harvesters, and by and large their slim profit margins have not been enough to cover debt service, thus leading to waves of bankruptcies and foreclosures. An alternative model will therefore have to reduce drastically the reliance on expensive off-farm inputs to help farmers out of this crisis. It is important to note that both overproduction and high production costs are results of the same produc-

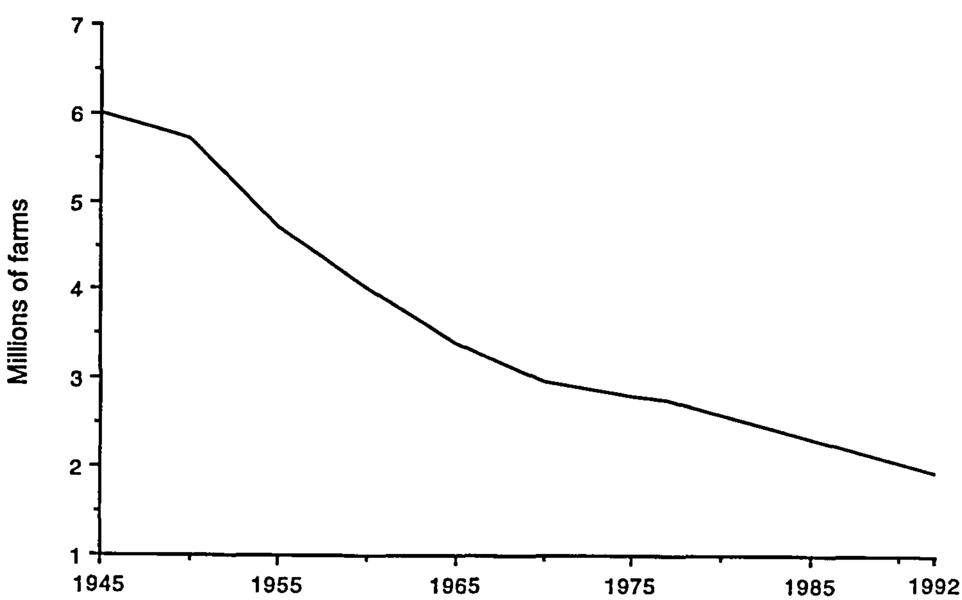


**Figure 1.** Number of farms in the United States, 1945–1992 (Source: Vogeler 1981; Holmes 1994).

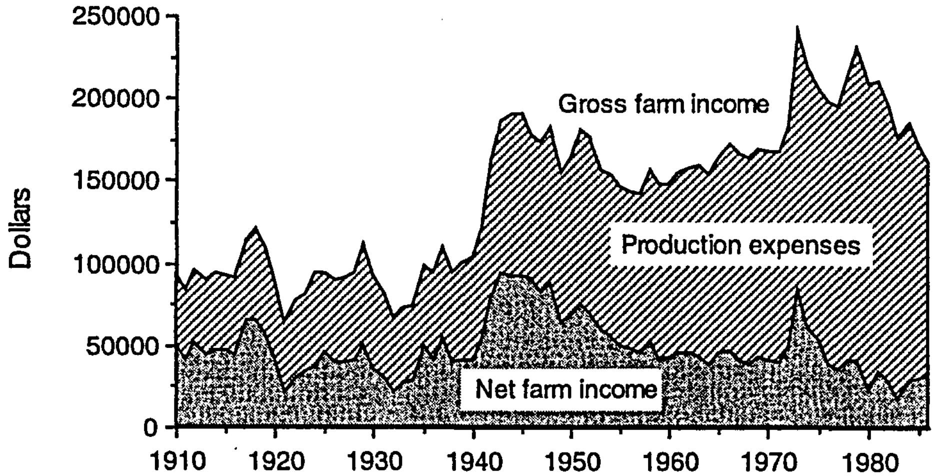


**Figure 2.** Gross farm income and production expenses in the United States, 1910–1986. (Source: U.S. Department of Agriculture 1990).



tionist technology, which is thus responsible for both the cost and the price sides of the economic squeeze affecting farmers.

## Ecological Dimensions

The clearest demonstration of ecological crisis is the leveling off of yield increases in the United States (Figures 3). In some places, yields are actually in decline (Hewitt and Smith 1995). There are different opinions as to the underlying causes of this phenomenon. Some believe that yields are leveling off because the maximum yield potential of current varieties is being approached, and therefore genetic engineering must be applied to the task of redesigning crop species (Tribe 1994). Agroecologists, on the other hand, believe that the leveling off is because of the steady erosion of the productive base of agriculture through unsustainable practices (e.g., Hewitt and Smith 1995; Altieri and Rosset 1995). Mechanisms to explain this process include land degradation though soil erosion, compaction, decline in organic matter and associated biodiversity, salinization, depletion of groundwater, deforestation, and desertification; and pest outbreaks because of widespread monoculture, genetic uniformity, the elimination of natural enemies, and the resistance of insects, weeds, and crop diseases to pesticides (Altieri 1995; Carroll, Vandermeer, and Rosset 1990; Goering, Norberg-Hodge, and Page 1993; Hewitt and Smith 1995). The declining efficacy of agrochemicals is symptomatic of these problems. In the first 30 years of the postwar period, pesticide use in the United States increased ten-fold, but percentage crop losses caused by insects doubled (Botrell 1979). A similar pattern is observed with chemical fertilizers; much larger doses must now be applied to obtain the yield increases that were once possible with much less use of chemical inputs (McGuinness 1993).

## Roots of the Crisis

The roots of these problems can be found in the socioeconomic context in which much of modern industrial agriculture was born. From the very beginning, U.S. agricultural sci-

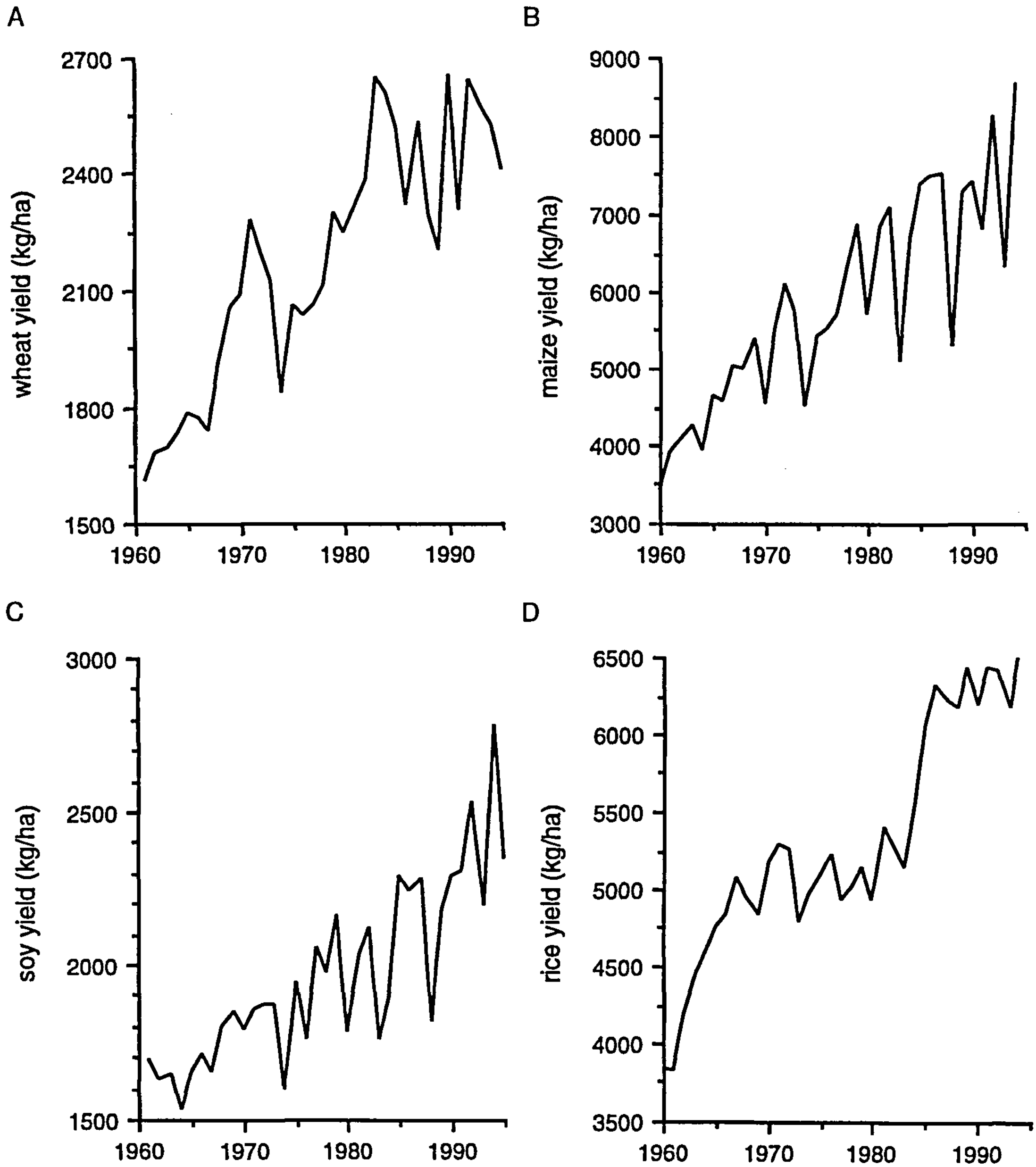


**Figure 3.** Yields of selected crops in the United States, 1960–1990. (Source: U.S. Department of Agriculture 1995a, 1995b; FAO-AGROSTAT 1990–1996).

ence was oriented toward maximizing the productivity of the most limiting factor of production in the North American economy: labor. Thus, early mechanization of agricultural practices led inexorably toward monoculture, despite its lowered efficiency or productivity of land. Agronomic science focused on varieties and planting densities for monoculture, then on chemical fertilizers to replace labor-intensive fertility-maintenance practices (e.g., manuring, crop rotations) with a simple chemical fix. Fertilizers permitted specialization—the separation in space of livestock and crops—which was further reinforced by the enormous investment in machinery needed to harvest a single crop. Extensive monoculture, with plants pumped up on nutrient solutions, then begat pest outbreaks, which were soon dealt with through labor-saving synthetic pesticides (Perelman 1977; Buttel 1990; Carroll et al. 1990; Goering et al. 1993; Altieri 1995).

The very nature of the social and economic forces that drove the generation of technology, then, has brought us to the present crisis. The costs of machinery, farm chemicals, and other inputs have favored large farm size, specialized production, crop monocultures, and mechanization. As farmers became integrated into international economies, imperatives to diversify disappeared as monocultures were rewarded by the economies of scale associated with mechanization; and many farmers went bankrupt because stagnant farm prices, even with subsidies, were insufficient to cover debt service. In turn, lack of rotation and diversification took away self-regulating mechanisms, turning monocultures into highly vulnerable agroecosystems dependent on high chemical inputs (Altieri 1995).

The same technology exported to the Third World has been even more catastrophic in its effects. Designed to maximize the productivity of a single resource that is scarce in the First World—labor—this technology has proven to be wasteful of land and capital. When exported to countries with chronic unemployment and little capital, it has rapidly led to enormous rural–urban migration, social problems, and the penetration of agriculture by foreign capital (Perelman 1977; Wright 1990; Goodman and Redclift 1991; Shiva 1991; Vandermeer and Perfecto 1995; Altieri 1995). Furthermore, when monocultural production systems have been transferred to the tropics at the expense of polycultural agroecosystems, the year-round growing season has made pest and pesticide problems spiral rapidly out of control (Altieri 1995; Conroy, Douglas, and Rosset 1996).

A key feature that emerges from an analysis of conventional agriculture and its crisis is the extent to which it has been penetrated by capital, and how that penetration serves further to intensify both the socioeconomic and environmental dimensions of the crisis (Buttel 1990; Lewontin 1982; Lewontin and Berlan 1986; de Janvry 1983; Goodman and Redclift 1991; Hamilton 1994). Historically, capital has proceeded to "appropriate" elements of the productive process, replacing natural pest control with pesticides, natural soil fertility with chemical fertilizers, and so forth (Goodman and Redclift 1991). The inevitable result is vested interests: Big money is at stake in maintaining the capital-intensive nature of modern farming, which makes countries and farmers dependent on suppliers of inputs. Clearly, immense profits would be lost if a move to alternatives and indigenous development paths were to lead to lowered dependence of farmers on off-farm inputs (van den Bosch 1978; Perelman 1977). This potential profit loss makes the entire agrarian system very resistant to change (Hamilton 1994).



## Sustainable Agriculture: An Adequate Response to the Crisis?

The crisis of agriculture, then, has both ecological and socioeconomic dimensions, which are interrelated and derive from the historic conditions of U.S. agriculture and the penetration of capital, serving both to deepen the crisis and to inhibit fundamental change. Any alternative paradigm that is to offer any hope of pulling agriculture out of crisis must address ecological, social, and economic forces. Focusing exclusively on ameliorating environmental impacts, for example, without addressing either the grim social reality that farmers face or the economic forces that perpetuate the crisis, is doomed to fail. This is precisely the concern that we raise with regard to sustainable agriculture.

The concept of sustainable agriculture is a relatively recent response to the decline in the quality of the natural resource or productive base associated with modern agriculture (Altieri 1995). The question of agricultural production has evolved from a purely technical basis to a more complex one characterized by social, cultural, political, and economic dimensions. The concept of sustainability has, however, been controversial and diffuse because of conflicting agendas, definitions, and interpretations of its meaning (Lélé 1991; Allen and van Dusen 1990; Allen 1993).

This concept has prompted much discussion, in turn generating diverse proposals for major adjustments in conventional agriculture to make it more environmentally, socially, and economically viable. The main focus has been to substitute less noxious inputs for the agrochemicals that are blamed for so many of the problems associated with conventional agriculture. Emphasis is now placed on purchased biological inputs such as *Bacillus thuringiensis*, a microbial pesticide that is now widely applied in place of chemical insecticides, and is marketed by major chemical companies under brand names like Dipel® and Javelin®. This type of technology pertains to a dominant technical approach called *input substitution.* The thrust is highly technological, with the limiting factor mentality that has driven conventional agricultural research in the past. Agronomists and other agricultural scientists have for generations been taught the "law of the minimum" as a central dogma. According to this dogma, at any given moment there is a single factor limiting yield increases, and that factor can be overcome with an appropriate external input. Once the hurdle of the first limiting factor has been surpassed—nitrogen deficiency, for example, with urea as the correct input—then yields may rise until another factor—pests, say—becomes limiting in turn. That factor then requires another input—pesticide in this case—and so on, perpetuating a process of treating symptoms rather than the real causes that evoked the ecological unbalance.

There are several problems with this approach. It focuses on the most superficial level of integration in the agroecosystem, that of a single species, the crop, with a single limiting factor, either abiotic or biotic. It denies the rich scientific basis provided by the science of ecology for the importance of higher levels of interaction, including synergism, antagonism, and multiple-species direct and indirect interactions. From a practical standpoint, the outcome of the limiting factor approach inevitably is that as a farmer "solves" one symptom, he or she is confronted with another, "unexpected" problem. If he or she uses urea to overcome nitrogen as a limiting factor, for example, he or she is all too often then confronted with an outbreak of insect pests with sucking mouth parts, whose numbers are dramatically increased by the greater availability of tree nitrogen in the plants' sap upon which they feed (McGuinness 1993).

Whereas classical agronomy focuses on these limiting factors, in the new science of agroecology we may think of them as symptoms that mask the underlying illness of an agroecosystem. In the hypothetical case of a nitrogen deficiency, rather than think of it as a limiting factor we may see it as symptomatic of an underlying systemic malaise such as a failure in the overall nutrient cycling mechanisms. In the case of land under long-term conventional management, often the real problem is a dead, sterile, chemically poisoned soil with little organic matter. Such a soil offers little in the way of nitrogen from either decaying organic matter or biological fixation, and its low porosity and compacted nature lead to the rapid surface runoff of externally applied chemical sources of nitrogen. In contrast, a healthy, biologically rich soil with ample organic matter and a diversity of microorganisms includes within its biota free-living nitrogen-fixing and nitrifying bacteria that mineralize nitrogen from the abundant organic matter. Rather than applying urea, then, the farmer should initiate a program designed to rebuild soil structure and organic matter, with an actively restored, healthy biotic community (Magdoff 1993). Thus agroecology is an alternative approach that goes beyond the use of alternative inputs to develop integrated agroecosystems with minimal dependence on external, off-farm inputs. The emphasis is on the design of complex agricultural systems in which ecological interactions and synergisms between biological components replace inputs to provide the mechanisms for sponsoring soil fertility, productivity, and crop protection (Altieri 1995).

## Current Practice Is Alarming

In this context, we find the prevalence of input substitution in alternative or "sustainable" agriculture to be alarming. Essentially, the capital-intensive, monoculture-based system of conventional agriculture is left intact. All changes are relatively minor. A toxic pesticide is removed, and a biological product substituted. Instead of, or in addition to, urea, manure or expensive commercial compost is trucked in. Although these changes may suggest a more environmentally benign direction, they leave in place the key forces that are driving the agricultural crisis: extensive monoculture, excessive use of machinery, input control by agribusiness, dependence on fossil fuels, and very high capital requirements. This approach addresses neither the debt trap that farmers are caught in because of high costs of machinery and inputs nor the ecological basis of declining yields—the reduction of functional biodiversity of agroecosystems.

Evidence for the increasing dominance of this faux-sustainable approach is everywhere. Organic farming, commonly viewed as a holistic concept, is now heavily commodified and embraced by capital. Publications directed at organic farmers are filled with advertisements for expensive biological pesticides, commercial compost, insectary-produced natural enemies, botanical extracts, microbial and other soil amendments, and the like. Natural food stores are now filled with almost as much processed food as ordinary supermarkets, except that the ingredients are "natural" or "organic," and less fiber has been discarded during their processing. Finally, whereas integrated pest management (IPM) was initially fought by the agrochemical companies (van den Bosch 1978), it is now heavily promoted by those who were once its detractors (Moore 1995; Western Crop Protection Association 1995). Why? Because corporate planners have come to realize that larger profits can be made from alternative practices than from conventional agriculture and they can still keep farmers hooked on off-farm technologies.

Pesticides are a case in point. The conventional broad-spectrum poisons that were once the mainstays of an industry are rapidly being lost from the market because of resistance of pests to them and, increasingly, the original patents are running out as the costs mandated by government regulation to introduce new chemical products becomes prohibitively high. For companies concerned about liability in the post-Bhopal world, biologicals and other new generation pesticides offer a convenient way out, as well as the chance to market themselves as good corporate citizens. As one industry group recently explained in a white paper on IPM (Western Crop Protection Association 1995, 9, 20–21):

> *IPM is not a formula to eliminate or reduce pesticide use.* . . . All aspects of agriculture have responded to the demand for minimal risk pesticides. . . . Farmers have become more conscious about environmental matters and have improved farming techniques. . . . As a result pesticide manufacturers have also responded by investing billions of dollars into research and by developing and marketing newer, more pest-specific and environmentally benign

> products. . . . There is a virtual revolution in pesticide research and development occurring today that will deliver even better pest management options to growers. The challenge facing regulators is to recognize and reward minimal risk pesticides. . . . (emphasis in original)

Eastern European and Third World factories now make methyl parathion (the leading culprit in insecticide poisoning of farmers and farmworkers worldwide), whose patent has run out, and it is available in Central America, for example, at a cost of about US $7 per liter. Because it is extremely dangerous to use and has lost much of its efficacy over time, internationally funded IPM programs, government extension agents, and commercial sales representatives now urge farmers to use new safe and effective biologicals like Javelin®, which may cost as much as $150 a liter, or even Avermec®, which may cost more than $400. These products are indeed safer, and in many cases more effective, than methyl parathion. Nevertheless, a question must be asked. In its crudest form this question is: "What is more injurious to the health of a farm family whose annual income may be well under $1,000 per year—exposure to the occasional whiff of methyl parathion or having to pay an additional $393 for an essential production input?" More generally, if alternative products raise production costs for First and Third World farmers already caught in a cost–price squeeze and increase their already excessive dependence on off-farm suppliers of inputs, then biopesticides do not offer a way out of crisis.[1]

Clearly the agrichemical industry knows which way the wind is blowing. Although actual figures are a closely guarded trade secret, it is widely believed that more than half of all research and development spending in the pesticide industry now goes toward biologicals. Because they are new products, their patents are fresh, so that monopoly prices may be charged and windfall profits reaped, and there is a ready-made marketing hook, given the movement toward IPM and other alternatives. It may seem easy to take a laissez-faire approach toward this development on the basis of the notion that it is better that the industry make profits from safe, environmentally sound products than from poisoning the environment. We, too, might share this feeling, were it not for the fact that farmers can ill afford further increases in production costs. Furthermore, input substitution technology does not offer a solution to the ecological underpinnings of the crisis. Finally, a better approach, agroecology, is available to us.

## Toward an Agroecological Approach

Agroecology has emerged as the discipline that provides the basic ecological principles for how to study, design, and manage alternative agroecosystems that address not just environmental/ecological aspects of the crisis of modern agriculture, but the economic, social, and cultural ones as well (Altieri 1995). Agroecology goes beyond a one-dimensional view of agroecosystems—their genetics, agronomy, edaphology, and the like—to embrace an understanding of the ecological and social levels of coevolution, structure, and function. Instead of focusing on one particular component of the agroecosystem, agroecology emphasizes the interrelatedness of all agroecosystem components and the complex dynamics of ecological processes. Current tendencies in agroecology encourage researchers to tap into the knowledge and skills of farmers, and to identify the potential for assembling biodiversity to create beneficial synergisms that provide the ability to remain at or return to a relatively stable state.

A closer look at ethnoscience (the knowledge system of an ethnic group that has originated locally and naturally) has revealed that local people's knowledge about the environment, vegetation, animals, and soils can be very detailed (Altieri 1995). Peasant knowledge about ecosystems usually results in multidimensional, productive land-use strategies, which generate, within certain ecological and technical limits, the food self-sufficiency of communities in particular regions. By understanding ecological features of traditional agriculture—such as the ability to bear risk, production efficiencies of symbiotic crop mixtures, recycling of materials, reliance on local resources and germplasm, and exploitation of a full range of microenvironments—it is possible to obtain important information that may be used for developing appropriate agricultural strategies tailored to the needs, preferences, and resource base of specific farmer groups and regional agroecosystems.

In essence, the behavior of agroecosystems depends on the interactions between the various biotic and abiotic components. By assembling a functional biodiversity it is possible to initiate synergisms, which subsidize agroecosystem processes by providing ecological services such as the activation of soil biology, the recycling of nutrients, and the enhancement of beneficial arthropods and antagonists. Agroecological technologies do not emphasize boosting yields under optimal conditions as Green Revolution technologies do, but rather they ensure constancy of production under a whole range of soil and climatic conditions—and most especially under marginal conditions, which usually prevail in small-farm agriculture. What is important, however, is to focus not on particular technologies, but on an assemblage of technologies that incorporate crop diversity, legume-based rotations, integration of animals, recycling, and use of biomass and residue management.

The production system must (1) reduce energy and resource use and regulate the overall energy input so that the output:input ratio is high; (2) reduce nutrient losses by effectively containing leaching, runoff, and erosion, and improve nutrient recycling through the use of legumes, organic manure and compost, and other effective recycling mechanisms; (3) encourage local production of food items adapted to the natural and socioeconomic setting; (4) sustain desired net output by preserving natural resources (by minimizing soil degradation); and (5) reduce costs and increase the efficiency and economic viability of small and medium-sized farms, thereby promoting a diverse, potentially resilient agricultural system (Altieri 1995).

The basic components of sustainable agroecosystem include (1) vegetative cover as an effective soil- and water-conserving measure, created through the use of no-till practices, mulch farming, use of cover crops, and the like; (2) a regular supply of organic matter through the regular addition of organic matter (manure and compost) and the promotion of soil biotic activity; (3) nutrient recycling mechanisms through the use of crop rotations, crop/livestock systems based on legumes, and the like; and (4) pest regulation through enhanced activity of biological control agents, achieved by introducing and/or conserving natural enemies (Altieri and Rosset 1995).

## Conclusions: Input Substitution versus the Agroecological Approach

As emphasized in this article, an agroecological strategy to achieve sustained agricultural productivity aims at breaking monoculture structure and dependence on off-farm inputs by designing integrated agroecosystems. This is the only approach with the potential to address both the socioeconomic aspects of the crisis—by reducing reliance on expensive off-farm inputs, whether they be biological or chemical—and the ecological devastation of modern industrial farming. Not only can the continued degradation of the productive base of agriculture be halted, but it can actually be reversed, as many agroecological tech-

**Table 1**
Characteristics of conventional, input substitution, and agroecological systems

| Characteristic | Technology: Conventional | Technology: Input substitution | Technology: Agroecological |
|---|---|---|---|
| Petroleum dependency | high | high | low |
| Labor requirements | low, hired | low, hired | high, family and communal |
| Management intensity | low | low-medium | more complex |
| Intensity of tillage | high | high to low | low, conservation |
| Plant diversity | low | low | high |
| Crops/varieties | annuals/hybrids | annuals/hybrid or open pollinated | annuals and perennials, local cultivars |
| Source of seeds | all purchased | purchased | some produced by farmer |
| Integration of crops and livestock | none | little (manure) | high degree of integration |
| Insect pests | very unpredictable | unpredictable | more stable |
| Insect management | chemical | IPM, thresholds, biopesticides, some biocontrol | cultural and biological |
| Weed management | chemical, tillage | novel bioherbicides | competition, crop rotation |
| Disease management | chemical, vertical resistance | antagonists, vertical resistance, multiline cultivars | rotation, horizontal resistance, mixed cultivars, and intercropping |
| Plant nutrition | chemical, applied in pulses, open systems | microbial biofertilizers, organic fertilizers, semi-open systems | reconstruction of living soils, semi-closed systems |
| Importance of decomposition and nutrient cycling | low | low to medium | high |
| Water management | conventional, large-scale irrigation | drip irrigation | artisanal and community irrigation, rainfed, organic matter, water traps |
| System response to perturbance | poor, high risk | poor, high risk | resistant, resilient, compensatory, less risk |
| Generation of technology | top-down, imported | top-down, imported | participatory, "farmer first," local |
| Research designs | conventional agronomic | conventional agronomic | participatory research |
| Insertion in the cash economy | total: buy inputs, sell produce | total: buy inputs, sell produce | buy less, more self-reliant, sales variable |
| Capital requirements | high | higher | low |
| Productivity of land | low to medium | low to medium | high |
| Labor productivity | highest | high | low to medium |
| Return to investment | high to low | low to medium | high |
| Net profitability | high to low | low to medium | variable |
| Health risks | high | medium to low | low |
| Environmental damage | high | medium | low |

niques have proven to permit the recovery of damaged soils and ecosystems. The end result of agroecological design is an improved economic and ecological sustainability of the agroecosystem, with proposed management systems specifically in tune with the local resource base and the operational framework of existing environmental and socioeconomic conditions.

Input substitution, on the other hand, does not take advantage of the effects of the integration of plant and animal biodiversity, which enhance complex interactions and synergisms. Input substitution can ameliorate some direct environmental impacts of agriculture, such as pesticide residues and resistance, but it does not reduce the fundamental vulnerability of monocultures. Furthermore, it replaces cheap, ecologically harmful inputs with benign but expensive ones, thus increasing costs and failing to address the economic crisis faced by the world's farmers.

Contrasting the agroecological approach with both conventional and input substitution technologies highlights the advantages of agroecologically designed integrated farming systems. These advantages include reduced vulnerability to pest, disease, and weed problems; lower dependency on off-farm inputs; lower capital requirements; and the higher land use efficiency associated with intercropping. In Table 1 we summarize the key characteristics of systems designed with conventional industrial, input substitution, and agroecological approaches. In general, agroecological technologies are both economically viable—they reduce costs of production by relying on local resources—and environmentally sound—they promote an efficient biological structuring, which in turn sponsors the functioning of the system. Farmers using this approach can rely on natural bioresources and local input sources rather than external inputs, resulting in considerable health, environmental, and socioeconomic benefits.

Agroecology provides a vision and guidelines for a more productive and diversified agriculture, one that is environmentally sound and also capable of preserving the social fabric of rural communities. However, this vision cannot be fully realized without an enabling policy scenario that encourages a truly sustainable agriculture. Such a scenario will mean removing existing disincentives and putting in place new incentives. Active participation of farmers' groups, in partnership with other institutions, will be essential to push for policies that work and to challenge research agendas that presently serve corporate interests at the expense of farmers and the environment (Pretty 1995).

Given the overall superiority of the agroecological approach, we believe it is urgent that we resist the proposition of a sustainable or organic agriculture based on mere input substitution, which provides an entry point for agribusiness to maintain control over farmers. The input substitution approach leaves us with a biologically vulnerable food supply; ecological instability; and the continued dependency, indebtedness, and impoverishment of the majority of the world's farmers. Agroecology, in contrast, offers the hope of a more self-reliant and viable farm economy, providing society with healthy food and protecting the environment for future generations.

## Note

1. An exception to this dilemma is the experience of the Cubans, who are facing an 80% drop in pesticide and fertilizer imports because of the collapse of trade with the former socialist bloc. In response they have established more than 200 cooperatively managed local biotechnology centers, which produce biopesticides and biofertilizers at low cost, using local resources and skills (Rosset and Benjamin 1994).

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