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Insight, part of Special Feature on Integrated Natural Resource Management

Integrating Research on Food and the Environment: an Exit Strategy from the Rational Fool Syndrome in Agricultural Science

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ABSTRACT

The thesis of this paper is that the "rational fool" syndrome can be applied to mainstream public sector agricultural research that is conducted in a way that is rational in the short term, but acts against its own long-term viability. Historically, a main concern of such research has been to maximize high levels of food production together with low prices to consumers. As a result, mainstream agricultural science has ignored negative impacts or externalities, which has contributed to a crisis of credibility with the general public and politically sensitive decision makers. A long-term strategic research agenda for the public sector is being defined that is new and relevant to present efforts to integrate natural resource management and sustainable agricultural production. Such an agenda must be understood as a way of managing natural resources for the production of food and environmental services essential to human well-being. If agricultural systems are viewed and managed as parts of whole ecosystems, the key properties of complex systems that need to be taken into account will force researchers to consider long-term effects and environmental externalities. Research products will then be increasingly strategic in nature, and the research process will be "democratized" as it involves and gains the support of a broad set of stakeholders. Private sector research cannot be expected to meet this need because strategic studies of resource management are required that cannot be made exclusive or proprietary and are, in other words, public goods. Several innovative research initiatives are under way that signal opportunities for change. This paper first elaborates on this argument and then illustrates key elements of the integrated natural resource management approach, with examples of approaches that show promise as alternatives to mainstream agricultural science. Although numerous and diverse, integrated approaches manifest several properties that can be defined as the keystones of a new paradigm.

KEY WORDS: ecosystem health, human health, natural resource management, rational fool syndrome, strategic research, sustainable agricultural production.

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INTRODUCTION

Amartya Sen described the "rational fool" as a person who makes self-interested decisions that are advantageous and logical in the short term, but ignores the personal negative effects of those decisions over the long run (Ridley 1996). This syndrome is commonly used to describe the environmentally destructive behavior of individuals and societies (Hardin 1968, Ostrom 1990). Although it not usually applied to the way food is produced, the syndrome can nevertheless be seen in action across the world in food production and consumption systems that ignore the negative effects of farming on human and environmental health. This does not mean that farmers are fools, but that mainstream agricultural science has organized information and developed technologies for food production in a way that provides society as well as farmers with a rationale for ignoring environmental, economic, and social costs over the long run.

Mainstream agricultural science treats natural resources as a storehouse of raw materials whose yields are to be maximized in the short term. Environmental goods such as clean water, flood protection, healthy soil, wildlife habitats, and biodiversity are not traditionally valued by mainstream agricultural science. The negative impacts of agriculture on the environment and other long-term effects of technical innovation are treated as external to the process of production and are not part of the costs for food paid by producers or consumers. In the short run, this science has proved to be enormously successful in increasing food production in high-income countries as well as in those low-income countries that have benefited from the agricultural production technologies of the Green Revolution. However, the long-term damage to the environment and human health that has resulted from this success is now being documented, and its cost is being calculated (Fowler 1990, Pimentel et al. 1992, Constanza et al. 1997). These findings provide a good illustration of the consequences of the rational fool syndrome.

Public goods research is defined as research that provides benefits for individuals and society that cannot be made exclusive or proprietary. When focused on the management of ecosystems to produce food, these research efforts should build a stock of useful knowledge that will enable human societies to sustain production and well-being over the long term. However, governments, agricultural research bureaucracies, and policy-making agencies in the public sector are no longer investing in long-term strategic research and, as a result, agricultural science is no longer creating the public goods needed to manage agroecosystems sustainably. This lack of support for strategic long-term research products that are also public goods is fueled by agricultural scientists' treatment of agricultural productivity as a separate issue from natural resource management and ecosystem health (Andersen 1998).

Low-income countries, in which support for public sector research is traditionally low and the institutions that provide research services are weak, are bailing out of public sector agricultural research at an ever faster rate. A recent survey of 208 sustainable agriculture projects in Latin America, Africa, and Asia showed that finding an alternative to mainstream agricultural science is just as much a preoccupation of farmers in low-income countries as it is of those in high-income countries. This survey found that nongovernmental and grass-roots initiatives were beginning to succeed in addressing the need for a type of agriculture that not only supplies food and other goods to farm families and consumers but also contributes to a range of public goods such as clean water, biodiversity conservation, and landscape enhancement. In these projects, most of which are in low-income countries, some 8.98×10^6 farmers have applied novel agriculture practices to 29×10^6 ha, up from an estimated 100,000 ha a decade ago. These innovative practices have been founded mainly on the experiences of farmers themselves as they experiment with and adapt technology, combined with efforts to build their capacity to apply ecological and biological principles that allow them to make better use of natural resources (Pretty and Hine 2001).

Research on managing ecosystems so that they continue to produce the food, fiber, and environmental goods and services on which human well-being and, ultimately, all life depend has to be done in the public sector. In the absence of exclusivity, the private sector has little incentive to invest in improved technology or management for the long run, because others who have not contributed to the cost of the investment will share the benefits. Ingenious schemes proliferate for creating private incentives for private individuals and firms to internalize environmental externalities. However, private enterprise by definition does not have a long-term interest in creating the type of long-term, strategic, public goods research products that are required to ensure a continuous stream of benefits from natural resources to society at large.

Strategic research products can be defined as those that have explanatory power, i.e., that explain why and how things work, as well as applications beyond the solution of a specific problem, need, or circumstance. In contrast, applied research products are developed primarily to produce a specific product or solve a specific problem in a well-defined set of circumstances. Strategic research also tends to be more of a long-term investment, and there is no time frame for the expected payoff, whereas applied research tends to be managed with relatively well-defined limits on expected length before completion. Finally, strategic research products are often public goods that maintain their value independent of the number of users and that cannot be made exclusive, i.e., no one can be barred from their use.

This paper argues that the persistence of a short-term, reductionist perspective on food production, together with an artificial separation of the management of human food systems from that of natural ecosystems, is rooted in a paradigm of science and organization of research that serves the interests of some, but not all, stakeholders. Those who benefit include food companies, agribusinesses, and producer groups who profit from the political economy of cheap food at the expense of environmental health. Worldwide, producers and consumers are becoming increasingly disenchanted with modern agriculture in both high- and low-income societies. A radical change is called for in the way that public goods research on food and the environment is carried out. The emergent properties of new approaches can already be detected in new ways of doing science and in new kinds of research organizations.

RESEARCH AND TECHNICAL INNOVATION IN MODERN AGRICULTURE

Public disillusionment with agricultural research

Compared to the Nobel prize-winning heights of the Green Revolution, the status and credibility of conventional or mainstream agricultural science have fallen drastically over the past decade, to the point that many people now see agriculture as a threat to the environment and to human health. The health concerns that the general public associates with agriculture fall into several areas:

- failures of modern agricultural science, such as the BSE (mad cow) disease syndrome and the foot-and-mouth outbreaks in the United Kingdom;
- bioengineered crops that introduce new allergens into the food chain, as occurred with Starlink corn, which contained a protein whose characteristics were associated with allergens and which was not approved for human consumption but nevertheless entered the human food chain;
- threats to the environment by genetically improved animals and fish such as salmon, which, were they to escape from their commercial pens, have a mating advantage that would threaten the genetic integrity of

wild stocks;
- the possible toxicity of genetically engineered crops to other life forms, e.g., BT corn, which could decimate Monarch butterfly populations;
- the development of herbicide resistance in weeds, e.g., generated by genetically engineered, herbicide-resistant soybeans that require the application of only a single herbicide.

These concerns are not restricted to high-income countries. For example, the large-scale spread of integrated pest management among thousands of small farmers in the tropics, where pesticide use has been greatly reduced, is motivated by their experience of the serious ecological imbalances and human health problems that pesticides can cause (Pingali and Roger 1995, Thrupp 1996). The way food is produced, the role of science in food production, the effects of new food production technologies on human health, and the well-being of ecosystems have become major political issues and topics for headline news. At local, regional, and global levels, the capacity of ecosystems to support human consumption of food and environmental goods and services is seen as threatened by modern agricultural practice.

Advances in agricultural science have the potential to significantly increase production in response to the globalization of trade and the food needs of a burgeoning world population. However, many perceive these advances as sources of undesirable changes in land use, climate, biodiversity, and the evolution of new diseases. As a result, a number of countries have based their national agricultural strategies on the World Conservation Strategy, which has an explicit priority requirement to " ... reduce excessive yields to sustainable levels ... " (Adams 1990:44).

Concern for the negative effects of agriculture on natural capital stocks is both an expression of the conservation ethic and a response to international poverty, famine, and disaster. This critique of mainstream agricultural research in the public sector is also applicable in societies in which national science bureaucracies are weak and research has been dominated by international entities financed by overseas development aid. The capacity of poor countries to withstand external shocks such as war, climate variations, and indebtedness depends partly on their natural capital. The diversity of natural capital gives it an important advantage over man-made capital in enhancing the survival of poor farmers in low-income countries, given that diverse ecosystems are more resilient to shocks and stress (Conway 1985, 1987, Pearce et al. 1990).

As a result of this critique of mainstream agricultural science, political support for mainstream agricultural research in the public sector is in decline (Andersen 1998), whereas increasing amounts of resources are now being devoted to environmental conservation and disaster relief for low-income countries. This loss of support reflects the disenchantment with modern agriculture in high-income countries and with research and advanced agricultural technology in both high- and low-income countries. Agricultural research is not unique in this loss of credibility: practitioners of rural development have also gone through a process of being proved consistently wrong (Chambers 1997). Critics of mainstream agricultural science find the research establishment " ... incapable of delivering social equity, economic efficiency, and ecological integrity in response to the decline of rural society and deepening crises in the depletion and degradation of water, soils, flora and fauna ... " (Campbell 1998:232-233). The rates of return on investment in agriculture in developing low-income countries are very disappointing. Much evidence is cited to support the view that returns on agricultural development projects have been lower overall than in other sectors such as health or education; in addition, the capacity of agricultural development projects to sustain momentum after external donors withdraw is seen as relatively low (Pretty 1995). Proponents of institutional change to support the development of sustainable agriculture find it hard to identify a clear role for agricultural research in this process. Röling and Jiggins (1998:297) state that " ... the old role of developing technologies FOR farmers seems to clash with the logic of ecologically sound farming, while a new role [for research] ... seems not to have clearly emerged."

Short-term success vs. long-term failure

For many years, mainstream agricultural science has been committed to a reductionist treatment of agricultural productivity and agriculture's role in development, as if these can be managed separately from natural resource management and ecosystem health. For example, one analysis of mainstream agricultural science equates natural resource management with location-specific adaptive research of little strategic value that is unlikely to produce internationally useful public goods and unworthy of significant levels of public sector investment (Anderson 1998).

A different type of analysis shows that, although discounting externalities may be a rational, albeit shortsighted, outcome of managing food production to maximize productivity and provide the lowest possible prices to consumers, it has significant costs in terms of human and ecosystem health (Pretty et al. 2000). Externalities related to agriculture affect the production and consumption behavior of individuals, households, interest groups, business firms, and governments. When producers shift some of the costs of production, whether health or environmental, onto other stakeholder groups, it becomes possible for them to produce at a higher level of output and profitability than if they had to offset the full costs against the gains. An important consequence of this is that, when negative externalities are present and costs shift away from producers onto others, the output that producers consider optimal is actually higher than the output deemed optimal by society as a whole.

A choice has been made to increase production and keep food prices low rather than provide a transparent accounting of the costs of care for human and agroecosystem health in agriculture (Pretty et al. 2000). With this in mind, conventional agricultural research has focused on the short-term goals of increasing yields and economic returns to producers and on delivering relatively low-priced food to consumers. Good historical reasons explain this focus, and extensive critiques, justification, and refutations of it abound, and will not be repeated here.

The main point is that agricultural research that focuses on increasing productivity and ignores externalities is largely built on technologies that maximize biological uniformity and sidestep, minimize, control, or destroy the natural biological processes that are essential to the stability and resilience of natural ecosystems (Folke et al. 1998). This is an issue for farmers in low-income as well as high-income countries. For example, small farmers in low-income countries are demonstrating how food production can be increased by enhancing the biological productivity of the soil, microenvironments, and even whole catchments (Pretty and Hines 2001). Ironically, perhaps the most powerful interest groups driving popular disaffection with the reductionist approach away from biological uniformity and toward diversity are well-off consumers who have the luxury of choice and whose preferences are expressed via specialized global markets. Their heightened concerns about the health and environmental implications of agriculture are creating significant demands for organic farming and niche products in subsegmented markets, and are encouraging farmers to diversify and integrate their activities with natural resource management (C. Wheatley, *personal communication*).

Research that treats environmental resources such as land, water, and biodiversity as discrete factors of production has, in fact, succeeded in increasing productivity in the short term. From this perspective, it is possible to maximize the productivity of individual factors of production by focusing research on improving management efficiency with new technologies. Because it works against, rather than building on, natural diversity, mainstream agricultural science is identified with processes that undermine ecosystem capacity to withstand or recover from shocks and stress. Increased production based on reducing variability slowly changes the functioning and resilience of the ecosystem that sustains the production of food and of the resources on which it depends. If variability and disturbances are not allowed to enter the system, they accumulate and return at a later stage on a much broader scale. Diminishing variability tends to increase the potential for larger-scale, less predictable, and less manageable disturbances that can have devastating effects on ecosystems (Ludwig et al. 1997); it also reduces the capacity of the ecosystem to provide the environmental services that are essential to material and energy stocks and to the flows that are important for food production. Agriculture based on blocking out variability or "disturbances" that are endogenous to the cyclic processes of ecosystem development is an expression of the rational fool syndrome, and the reductionist treatment of natural variability is the " ... short-term success that leads to long-run failure ... " (Folke et al. 1998:458).

Integrated approaches to research on agriculture and resource management have to bring about three critical changes to achieve the paradigm shift needed to lever food production and ecosystem and human health out of the current unsustainable syndrome. First, research for agriculture must be understood as one way of managing natural resources to support human livelihood. As such, it must build a strategic research agenda that is based on working with variability and view functional ecosystem disturbances as desirable features of sound resource management and food production. Second, research needs to be linked to active processes of adaptive management in ecosystems of high priority to important stakeholders engaged in both research and management. Third, the appropriate organizations for carrying out this research need the support of the emergent interest groups and learning communities that are propelling a paradigm shift outside of and virtually despite mainstream agricultural science.

An example of working with variability

A classic example of a paradigm shift lies in the history of the management of African pastoral systems (Ellis and

Swift 1988). Recommended methods of reducing overgrazing in these pastoral systems included group ranches, grazing blocks, and associations in which pastoralists were confined to particular tracts of land to better regulate the interaction between animals and plants and raise productivity. Over time, these new management methods were found to destabilize grazing systems that are characterized by intra-annual variability resulting from frequent drought. In contrast, pastoralists using traditional methods cope with multiyear drought by dispersing into small herds and groups over a wider area, thus expanding the spatial scale of exploitation. In nondrought periods, pastoralists ensure that unused space or an ungrazed reserve is available for periods of drought by stocking some areas in the ecosystem well below their average carrying capacity (undergrazing) while overgrazing others. This stabilizing mechanism relies on mobility, whereas the modern management strategy is based on confinement. In other words, recommendations that do not factor in variability and disturbance in the ecosystem often lead to long-term failure. Research had to define alternatives to conventional management of grazing systems that functioned at the ecosystem level, took into account hierarchies of interdependent subsystems, and were effective over the long term. Technical packages designed for a reduced spatial scale and short time horizon could not cope with the variability in the system, and indeed became associated with increased degradation in the long run (Ellis and Swift 1988).

An example of working with adaptive management

The experience of the Forages for Smallholders Project (FSP) (P. Kerridge et al., *unpublished manuscript*) with the introduction of legumes and grasses into small-farm production systems in southeast Asia illustrates how a mixture of participatory learning and research can support an integrated approach to food production and natural resource management. This type of approach fosters adaptive management that is responsive to and supportive of variability in ecosystems.

The project is introducing of a large variety of optional, new, multipurpose legume and grass species using participatory methods that enable farmers to learn about diversity and devise a variety of niches for different species in their systems. The use of a menu of diverse options for participatory learning is fundamental to this approach. Farmers learn, invent, and validate new ways of using diverse species, and the ways they choose are becoming more complex as the farmers gain experience.

Over time, farmer preferences for varieties and characteristics have changed. At first, animal feed, contour hedgerows, and intensive cut-and-carry plots emerged as the main ways in which farmers integrated several species into their agricultural systems. Subsequently, other ways of integrating legumes and grasses into living fences, ground covers, and small grazed plots evolved for many different end uses. Species and genetic diversity as well as new ways of coupling plants and animals in the system, e.g., growing shrub legumes for forage as part of contour rows for soil erosion control, have been developed as a result of farmer innovations. Participatory research fostered adaptive management that enabled the project to encompass the diversity and complexity of entire agricultural systems. The researchers, whose initial ideas about appropriate options for each farming system did not agree with those of the farmers, eventually revised their opinions to reflect the fact that the farmers' grasp of complexity was different than their own.

Researchers' innovations have also been adapted in unexpected ways. For example, on steeply sloping lands, farmers introduced contour plantings of *Paspalum atratum,* which establishes much more rapidly and cheaply than the heavily promoted vetiver grass and can also be used for fodder. *P. atratum* competes with associated crops, but not to the same extent as other types of barriers. The farmers took an integrated approach to managing small areas planted with legumes for forage and also used alternative feed sources from adjacent forest and waste areas. In this way, they highlighted for the project the potential of managing both types of land use for the preservation and increased use of indigenous species.

New organizational concepts

Eighteen projects in geographically representative regions of the United States make up the Integrated Farming Systems (IFS). These projects are linked in a network that makes it possible to share knowledge and experience among farmers, scientists, consumers, policy makers, bankers, and producers and distributors of agricultural inputs. The goals of the IFS are to help farmers discover and use more sustainable farming practices and to help communities identify and overcome barriers to adopting more sustainable practices and systems (Fisk et al. 1998). A highly important feature of the network is that it also seeks and creates leverage for catalyzing policy change on the basis of experience gained in the context of an adaptive management approach to sustainable agriculture. The use of formative evaluation to document progress, reflect on what works, and determine the next steps to take has been crucial to this catalysis (Fisk et al. 1998).

As stated above, one goal was to help farmers find and use more sustainable farming practices with the support of their communities and of policy makers. To achieve this, the IFS set out to establish a "learning community" that practices the five disciplines identified by Senge (1990) as the requisites of a learning organization. By self-consciously working together around the idea of creating a learning community, the IFS has successfully built a support structure for farmers and community spokespersons that favors sustainable farming. Farmer-driven research and educational organization are key elements: farmers conduct on-farm research, educate other farmers and community members, and provide laboratories that foster leadership. As a result, a cadre of community-based spokespersons has been developed who can effectively carry messages about their needs and achievements to decision makers and opinion leaders in their own communities and centers of policy activity. Policy makers in the United States are looking to community-based organizations for information about the effects of policy changes at the farm and community levels. Among its 18 projects, the IFS has provided some powerful demonstrations that have helped to educate policy makers (Fisk et al. 1998).

An important ingredient of this success is an effective strategy for working across different organizational scales. To achieve this, the IFS helps communities to engage large institutions by finding the constituency that these organizations are most likely to listen to and building a relationship with that constituency. The IFS has been highly effective in communicating information and developing leadership skills to catalyze action on national policy issues. One result of this is that the U.S. Department of Agriculture now uses the IFS model.

Agriculture as a way of managing natural ecosystems for human well-being

Several novel approaches are helping to integrate agriculture and natural resource management, although there is still no coherent unity of thought or organization. Scientists have called for a broader focus and created new names for these approaches, all of which emphasize a balance between productivity and environmental health objectives and, to varying degrees, view agriculture as one way of managing natural ecosystems for human well-being. Much of this thinking parallels the processes that have been developing for many years within applied research projects and programs focused on adaptive farming systems (D. Gibbon, *unpublished manuscript*).

These new perspectives are built on the premise that human health and livelihood depend on the functioning of ecosystems that generate essential natural resources and environmental services, play a fundamental role in supporting life, and are essential to the material cycles important for food production. Environmental services include regulating climate variability, water quality, and water quantity; controlling floods and pests; assimilating wastes; recycling nutrients; generating soil; pollinating crops; and maintaining the composition of the atmosphere, biodiversity, and the landscape (Conway 1997).

The idea that the methods used by traditional cultures to manage food production are integral to natural resource management has also helped to break down the reductionist separation of agriculture and ecosystem management. Many documented examples illustrate indigenous systems for managing whole landscapes as integrated farming systems; these range from the upland forest all the way to the coral reef (Folke et al. 1998).

Once agricultural systems are understood to be parts of, and managed like, ecosystems, research needs to take into account the effects of agriculture on the environment. Ecosystems are "holarchies" made up of many different components or "holons" that operate together. A holon is a whole system that is made up of smaller parts and at the same time forms part of a larger system (Allan and Starr 1982, Giampietro and Pastore 1999). This concept is useful in illustrating how agriculture involves interventions in component systems that are hierarchically organized on several scales: soil microorganisms, populations of species, fields in a landscape, etc. In contrast to mainstream agricultural science, new approaches that integrate food production and environmental health objectives analyze agriculture as a set of interventions in a hierarchical system. This helps to emphasize the fact that ecologically sound conditions for growing healthy animals and plants must usually be created at more than one system level, that is, higher than the plot or even the farm, and must be managed on a landscape scale (Holling et al. 1995). This was the approach used to define a successful management strategy for African pastoral systems.

Agricultural systems manifest an important characteristric of holarchies or hierarchies of interdependent subsystems: what is good in the short term is not necessarily good in the long term (Giampetro and Pastore

1999). Understanding the holarchic structure of agricultural systems is crucial to the recognition that knowledge of what goes on at one level of a holarchy does not necessarily provide sound information about what is going on at other levels. For example, increasing productivity at the level of individual plots can reduce the overall productivity of a whole landscape such as a watershed, and pest and disease control to improve plant health in the farming system can jeopardize human health in the larger production-to-consumption system.

Research on agriculture treated as one component of human intervention in complex ecosystems will need to be increasingly strategic in nature. This type of research must deal with a high level of uncertainty based on patterns that are repeated in an irregular way. These are also known as fractals: generic patterns repeated in a self-similar way at many different levels that are always recognizable but never exactly the same. In principle, research can design an agricultural system or subsystem with a generic pattern and potential, establish the conditions required for it, and predict the dynamics that will produce a recognizable variant of this system. Action research is an approach that has potential applications in this kind of situation because it allows researchers to intervene in an agroecosystem, study the effects of the intervention, and apply this understanding to a second intervention. Research efforts of this type can be conducted to push a system into a phase of instability and change within certain constraints, monitor the resulting adaptive management process, and use the feedback to develop management principles. However, research cannot determine the specific form of the generic pattern that may emerge. For this reason, research that builds on variability will not produce technological "silver bullets" in the way that reductionist agriculture has: its focus by definition must be on the strategic and the generic, on "how" rather than "what" to change in agriculture. The adaptive management of species diversity in the Forages for Smallholders project is an example of this shift in approach.

In agriculture, new technologies based on the active reduction of variability in the flow of a resource or a natural capital have, in fact, succeeded in increasing productivity at one level of the holarchy or in one of a series of interdependent systems. In mainstream agricultural science, new technology is designed to reduce and overcome fluctuations and variability in nature and to block out the natural disturbances that are functional and necessary for sustaining ecosystem resilience (Folke et al. 1998). To a very large extent, the anomalies that are fueling public disenchantment with mainstream agricultural science are instances in which success in overcoming variability in the short term in one part of the system has led to failure in the long term at another level.

ORGANIZING FOR INTEGRATED RESEARCH APPROACHES

Once it is understood to be a form of natural resource management, agricultural science must definitely be subject to the value-driven preferences of diverse interest groups or learning communities. Resource management involves negotiating goals and acceptable trade-offs among multiple stakeholders, including the different learning communities. For poor farmers in semisubsistence agriculture, there are trade-offs between satisfying the family's daily food and income needs and maintaining the viability of the natural resources required to produce them. For better-off farmers in commerical agriculture, there are trade-offs between cutting costs to capture slender profit margins and long-run investment in the management practices and technology needed to sustain productivity. Research aimed at improving the management of ecosystems for food production and other purposes has to incorporate the management objectives of the different stakeholders with regard to how best to use natural processes, cope with disturbances, and internalize externalities.

This has several implications for the organization of research intended to integrate the objectives of food production and environmental health. The democratization of science, which in this case is understood to mean the inclusion of lay expertise and values in the process of planning and carrying out research, may be a prerequisite to improving the quality of scientific understanding and obtaining support for the research. In particular, extended peer communities, especially the stakeholders affected by an environmental problem, need to be involved in science when cause-and-effect relationships are unclear and when research measurement and ethical aspects have a high level of uncertainty (Funtowicz and Ravtz 1993, Irwin 1995). The present debate about integrated approaches heightens the need to include lay expertise and to cease restricting the conduct of research to technical specialists. Including citizen expertise when reforming science bureaucracies is essential, because research that integrates the objectives of food production and environmental health will require input from various realms of knowledge. New kinds of organizations that aim to carry out research based on integrated approaches must be prepared to consider knowledge that has not been scientifically generated, deal with a plurality of knowledge forms rather than a unitary consensus, take into account stakeholders' concerns, and be extremely flexible. The IFS illustrates this type of institutional approach.

Institutional flexibility is required to enable diverse stakeholders to carry out a paradigm shift toward integrated approaches. Research organizations must be learning organizations that can not only conduct strategic research but also monitor and provide feedback on adaptive management projects for agroecosystems. In this respect, there is a notable lack of fit between conventional management institutions and ecosystems, in particular agroecosystems that require adaptive management, and some observers see this lack of fit as a " ... crisis of institutional learning ... " (Folke et al. 1998).

An important organizational feature needed to implement integrated approaches is a flexible hierarchy that enables decision makers to interact at different ecosystem levels. Researchers need to interact with the nonscientists who form part of extended learning communities. This organizational feature is missing in conventional agricultural science bureaucracies. An organizational type with this potential for flexibility and learning was identified in the mid-20th century as an "adhocracy" (Mintzberg and McHugh 1985), but it was not formally used to manage agricultural science until recently. An adhocracy is characterized by the production of complex outputs that demand sophisticated innovation by combinations of experts deployed in temporary teams to work on projects. In an adhocracy, coordination is achieved less by direct supervision, performance controls, and rules than by selective decentralization. The power to make decisions is decentralized in uneven ways, and devolves to the level or person most likely to have the expertise needed to deal with the issue at hand.

Three elements of organizational change in an adhocracy are well suited to the current need to promote organizational change in support of integrated research approaches in agricultural science. First, management usually allows patterns of working together to emerge in a self-organizing way. Second, strategies can be developed by unusual nodes in the organization and adopted by the collectivity. Third, management has to create a climate in which a wide variety of strategies can grow, watch what comes up, and tolerate the unexpected. This approach to change is consistent with the needs of research linked to the adaptive management of ecosystems.

Many of the organizational features of the adhocracy coincide with those identified with learning organizations. Senge (1990) mentions these characteristics: a willingness to take risks and experiment, decentralized decision making, systems for sharing learning and putting it into practice, frequent use of cross-functional work teams, opportunities to learn from experience on a daily basis, a culture of feedback and disclosure, and collective vision building. Finally, the learning organization is closely connected to its environment, which includes legislators, regulators, clients, competitors, and communities.

The disestablishment of science bureaucracies, which have been the home of agricultural research over the past 100−150 yr, is occurring at breakneck speed in both high- and low-income countries, largely as a result of public disenchantment with, and the subsequent loss of political support for, the reductionist type of agriculture described earlier. The design of new organizational forms for carrying out alternative integrated approaches to research is also under way in a highly decentralized and self-organizing process. Participatory research approaches provide alternative ways to democratize science. Social and institutional issues of strategic importance to the future of ecosystems and human health care have only recently begun to emerge as a research topic (Folke et al. 1998). Although a systematic overview of this process of self-organizing change is lacking, its main features, which can be determined from the projects already in place, correspond to the principles embodied in flexible learning organizations.

Keystone properties of research that integrates food production and environmental health objectives

Emergent alternative approaches have in common an integrated approach, which treats agriculture as one element of human intervention in ecosystems. Although numerous and diverse, these integrated approaches manifest several common elements; in particular, they:

- integrate research and adaptive management of food production with ecosystem and human health by taking ecosystem and human health externalities into account in food production and marketing;
- recognize that agricultural science is not the exclusive domain of scientists and that internalizing environmental and human health externalities involves negotiating trade-offs that depend on value judgements by different stakeholders;

- conduct strategic long-term research that works with and for sustained ecological, economic, and sociocultural variability;
- assign priorities to strategic research based on an understanding of the dynamics of cause and effect in ecosystems (including agroecosystems) across hierarchical system levels;
- approach agriculture as an element in ecosystem management, from an area perspective, and not exclusively as commodity-based or as factor research;
- incorporate adaptive management into research so that these domains interact to provide rapid feedback to the relevant learning community responsible for food production and for ecosystem and human health;
- carry out adaptive management experiments that include interventions of different types (e.g., policy, technology, collective action) at various scales to achieve understanding when scale and uncertainty make positivistic experimentation difficult;
- support the development of information management decision support and other ways of being responsive to and supportive of ecosystem variability as premium strategic research products (e.g., good monitoring and diagnostic tools able to detect change);
- ensure that their scientific method and research organization are diverse and responsive to variability and built on the principles of learning organizations, so that both provide capacity for enhancing the resilience of ecosystems;
- organize decision-making hierarchies that involve scientists, managers, and other kinds of stakeholders in research and adaptive management that match the ecological hierarchy of scales affected by the pertinent stakeholder objectives and ecosystem management issues;
- incorporate into agricultural research explicit considerations of the preferences of competing interest groups in different kinds of trade-offs between productivity and environmental health;
- foster learning communities with research and adaptive management functions, ensure interaction between research and management expertise, and break down barriers between different kinds of knowledge (e.g., expert and layman); and
- organize learning communities to work with multiple stakeholders in areas such as negotiation platforms, conflict resolution, facilitation, participatory research, and learning to make the value judgements required to arrive at acceptable trade-offs among competing goals for the same resources.

CONCLUSION

A powerful critique of mainstream agricultural science is gaining currency based on the broadly perceived anomaly of cheap, plentiful, but purportedly unhealthy food produced by environmentally destructive farming practices in combination with persistent global poverty and inequity in access to food. Farmers in low-income countries as well as producers and consumers in high-income countries are demonstrating in various ways their desire for a different approach that balances the need for food with environmental health.

Mainstream agricultural science has traditionally treated food and fiber production as a separate domain of enquiry from the management of natural resources and the environment; this attitude facilitated increases in productivity that ignored the negative effects of agriculture on the environment and human health. A long-term strategic research agenda for the public sector is being defined that is new and relevant to integrated natural resource management and sustainable agricultural production. Such an agenda must be understood as a way of managing natural resources for the production of food and the environmental services essential to human well-being. This paper has identified a number of keystone properties of emergent approaches that suggest the future directions needed for change and innovation in agricultural science.

RESPONSES TO THIS ARTICLE

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LITERATURE CITED

Adams, W. M. 1990. *Green development.* Oxford University Press, Oxford, UK.

Allan T. F. H., and T. B. Starr. 1982. *Hierarchy.* University of Chicago Press, Chicago, Illinois, USA.

Anderson, J. R. 1998. Selected policy issues in international agricultural research: on striving for public goods in an era of donor fatigue. *World Development* **26**(6):1149-1162.

Campbell, A. 1998. Fomenting synergy: experiences with facilitating landcare in Australia. Pages 232-249 *in* N. G. Röling and M. A. E. Wagemakers, editors. *Sustainable agriculture and participatory learning.* Cambridge University Press, Cambridge, UK.

Chambers, R. 1997. *Whose reality counts? Putting the last first.* Intermediate Technology, London, UK.

Constanza, R., R. d'Agre, R. de Groot., S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neil, J. Paruelo, R. G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* **387**:260-287.

Conway, G. R. 1985. Agroecosystem analysis. *Agricultural Administration* **20**:31-55.

Conway, G. R. 1987. The properties of agroecosystems. *Agricultural Systems* **24**:95-117.

Conway, G. R. 1997. *The doubly green revolution: food for all in the 21st century.* Penguin, London, UK.

Ellis, J. E., and D. M. Swift. 1988. Stability of African pastoral ecosystems: alternate paradigms and implications for development. *Journal of Range Management* **41**(6):450-458.

Fisk, J. W., O. B. Hesterman, and T. L. Thorburn. 1998. Integrated farming systems: a sustainable agriculture learning community in the USA. Pages 217-231 *in* N. G. Röling and M. A. E. Wagemakers, editors. *Facilitating sustainable agriculture.* Cambridge University Press, Cambridge, UK.

Folke, C., L. Pritchard Jr., F. Berkes, J. Coling, and U. Svedin. 1998. *The problem of fit between ecosystems and institutions.* Working Paper Number 2. International Human Dimensions Program on Global Environmental Change, Bonn, Germany. Available online at: http://www.uni-bonn.de/ihdp/WorkingPaper02/WP02m.htm.

Fowler, C., and P. Mooney. 1990. *The threatened gene: food, policies and the loss of genetic diversity.* Lutterworth, Cambridge, UK.

Funtowicz, S. O., and J. R. Ravtz. 1993. Science for the post-normal age. *Futures* **25**:739-755.

Giampetro, M., and G. Pastore. 1999. Multi-dimensional reading of the dynamics of rural intensification in China: the amoeba approach. *Critical Reviews in Plant Sciences* **18**(3):299-329.

Hardin, G. 1968. The tragedy of the commons. *Science* **168**:1243-1248.

Holling, C. S., D. W. Schindler, B. H. Walker, and J. Roughgarden. 1995. Biodiversity in the functioning of ecosystems: an ecological synthesis. Pages 44-83 *in* C. A. Perrings, K.-G. Maler, C. Folke, C. S. Holling, and B.-O. Jansson, editors. *Biodiversity loss: economic and ecological issues.* Cambridge University Press, Cambridge, UK.

Irwin, A. 1995. *Citizen science: a study of people, expertise and sustainable development.* Routledge, London, UK.

Ludwig, D., B. Walker, and C. S. Holling. 1997. Sustainability, stability and resilience. *Conservation Ecology* **1** (1):7. [online] URL: http://www.consecol.org/vol1/iss1/art7.

Mintzberg, H., and A. McHugh. 1985. Strategy formation in an adhocracy. *Administrative Science Quarterly* **30**:160-197.

Ostrom, E. 1990. *Governing the commons: the evolution of institutions for collective action.* Cambridge University Press, Cambridge, UK.

Pearce, J., D. Barbier, and A. Markandya. 1990. *Sustainable development: economics and environment in the Third World.* Edward Elgar, Aldershot, UK.

Pimentel, D., H. Acguay, M. Biltonen, P. Rice, M. Silva, J. Nelson, V. Lipner, S. Giordano, A. Harowiz, and M. D'Amore. 1992. Environmental and economic cost of pesticide use. *Bioscience* **42**(10):750-760.

Pingali, P. L., and P. Roger. 1995. *Impact of pesticides on farmers' health and the rice environment.* Kluwer Academic, Dordrecht, The Netherlands.

Pretty, J. 1995. *Regenerating agriculture: policies and practice for sustainability and self-reliance.* Earthscan, London, UK.

Pretty, J., C. Brett, D. Gee, R. Hine, C. F. Mason J. I. L. Morison, H. Raven, M. Rayment, and G. van der Bijl. 2000. An assessment of the total external costs of UK agriculture. *Agricultural Systems* **65**(2):113-136.

Pretty, J., and R. Hine. 2001. *Reducing food poverty with sustainable agriculture: a summary of new evidence; final report from the SAFE-World Research Project.* University of Essex, Cochester, UK.

Ridley, M. 1996. *The origins of virtue: human instincts and the evolution of cooperation.* Penguin, London, UK.

Röling, N. G., and J. Jiggins. 1998. The ecological knowledge system. Pages 283-311 *in* N. G. Röling and M. A. E. Wagemakers, editors. *Facilitating sustainable agriculture.* Cambridge University Press, Cambridge, UK.

Senge, P. M. 1990. *The fifth discipline: the art and practice of the learning organization.* Doubleday-Currency, New York, New York, USA.

Thrupp, L. A. 1996. *Partnerships for sustainable agriculture.* World Resources Institute, Washington, D.C., USA.

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