KEYNOTE ADDRESS

Systems Thinking and Practice in Agriculture

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ABSTRACT

Reductionist science with its positivistic philosophical roots and experimental research practices has generally served agriculture well for around 150 yr. Technological innovations based on the propositions generated through this paradigm have played a profound role in the extraordinary productivity growth that has occurred in agriculture across the globe.

Yet with recognition of its success in this context is the realization of its inadequacies from broader perspectives. There is an increasing sense of unease about degradation of biophysical environments, distortions of socio-economic environments, and dislocations of cultural environments too often associated with agricultural practices. There are calls for a new science and praxis of complexity to deal with these problematic relationships between agriculture and the environments in which it is conducted. Systems thinking and practices are emerging as useful in this regard. Two schools are apparent within this broad movement. The first ("hard") approach comes from a pedigree that includes systems analysis, systems engineering, cybernetics, and ecosystem biology. Assuming a world of transforming systems, the "hard" systems scientists in agriculture seek to design new agro-ecosystems that are at once productive, stable, equitable, and sustainable. In the "soft" approach, with its foundation in cognitive science, the systemicity is transferred from the world to the way of investigating the world.

This new paradigm presents considerable challenge to conventional methods and methodologies in research, education, and extension in contemporary agriculture.

(Key words: systems, thinking, agriculture)

Abbreviation key: FSR = Farming Systems Research.

PREFACE

Given the superior power and scope of the new idea, we might expect it to prevail rather quickly, but that almost never happens. The problem is that you can’t embrace the new paradigm unless you let go of the old.

Marilyn Ferguson – The Aquarian Conspiracy

The basic proposition of this paper is that it is time to let go of the old paradigm of agricultural science and embrace the new. This is a profoundly difficult task. I have not only to make the case for a change in the first place but also to capture and relay the essence of the new. This must be done in the face of 1) a clear recognition of the long history of success of the prevailing paradigm; 2) the comfortable certainty of the familiar; and 3) some significant confusion about the essence and details of the "systems approaches" to agriculture. Under such circumstances, I am quite aware that I risk the "fierce controversies, international name-calling, and the dissolution of old friendships" that Thomas Kuhn (40) posits are common outcomes of debates about paradigm shifts!

What I propose, however, comes at a time in American history singularly less controversial and turbulent than at the birth of the "old" agricultural science in this country 140 yr or so ago. It is almost inconceivable now that the reductionism and gradualism of the sciences of von Liebig, Mendel, Darwin, and Pasteur and of the incrementalism and rationalism of the neo-economists, Menger and Walras and Je-
rons, could have been adopted in such chaotic times as the Civil War. Yet maybe this is exactly why they were. Maybe it was when all looked bleak and incredibly uncertain, and complex, that humankind turned to science and technology to simplify complexity and thereby discover "truth" about the world as the basis for developing guides for a more certain future.

Few can doubt the success of the application of what we might term the Liebigian paradigm—based as it is on the law of the minimum—to the growth in agricultural production. In the US alone, it has been estimated (35) that gross agricultural production increased sevenfold between 1880 and 1980, essentially through technological innovation. Prima facie it would be hard to sustain that the science of simplification, which spawned such progress, is now inadequate, yet this is the position that I, among many others, now suggest.

THE SENSE OF UNEASE

The sense of unease about the inadequacy of reductionistic science in agriculture (as well as in many other areas of human endeavor) comes precisely because of increasing evidence that in dealing with complexity by simplifying it to "manageable bits", we fail to come to terms with the "real issues" facing humankind. Among these lie basic questions about the way we interrelate with our environments.

There is increasing concern that much of the progress in agricultural productivity is only being achieved at the cost of long-term degradation of its biophysical and sociocultural environments. Symptoms of serious inequities in the trade-offs between the needs of the present and those of the future are beginning to cause serious alarm as a wide spectrum of society tries to grapple with issues as complex as global warming and environmental degradation. Within the domain of agriculture, "a Greek chorus of criticism" is now being heard of US agricultural institutions. Among the reasons cited for this are:

... environmental degradation; concerns for animal welfare; impacts on the health and safety of farmers, agricultural workers and consumers; adverse nutritional effects of production and processing technologies; the extrusion of smaller family farms from agriculture; the erosion of rural communities and the concentration of agricultural production and economic wealth; adequate conservation and commercial exploitation of fragile lands that should not be in cultivation. (7).

And all this in the face of the obscene paradox where "... massive food surpluses co-exist with hunger, obesity and concerns that the diet is unsafe and/or of low nutritional value" (17).

In the Third World, the situation is even more serious.

Robert Chambers (12) puts it more brutally: "... the extremes of rural poverty in the third world, are an outrage," and this in spite of the dramatic increases in agricultural productivity associated with the "green revolution".

That the issue is profound, even within the US, is reinforced by the submission that:

... although bankruptcies and foreclosures have dramatized the current farm crisis, agriculture's underlying problems extend well beyond economics to the long term sustainability of the system itself. (66).

As agriculturists, we need to rethink our fundamental perspectives on what we actually mean by improvements in agricultural and rural development. The language of reductionism and positivism does not entertain the very complex and dynamic phenomenon associated with the quest for sustainable practices.

As "new perspectives give birth to new historic ages" (24), it is clearly time to argue loudly for a shift in thinking from the influence of the Age of Productivity to that of the new Age of Persistence. This submission is a contribution to that shout as it highlights the imperative for a new research paradigm in the tradition of what has been called "the science and praxis of complexity" (60): a paradigm that can accommodate complexity, uncertainty, and even chaos, both as aspects of the world itself and of the way we humans construe meanings of it. The issue of sustainability or persistence illustrates this well. As has been pointed out "... agricultural sustainability can
be defined in different ways and sought through different means” (22). To some, sustainability relates to the sufficiency of food, with agriculture being regarded by such a constituency, as primarily “... an instrument for feeding the world.” A second group recognizes sustainability in an ecological context with a concern for the disruption of biophysical ecological balances by “nonharmonious practices”. To a third group, the concept of sustainability extends to

... promoting vital, coherent, rural cultures and encouraging the values of stewardship, self-reliance, humility and holism which ... have been most associated with family farming.

Following Cotgrove (20) and Miller (47), a fourth, “mystic” position can be added to this array in presenting a world view that environmental problems caused through agricultural (mal)practices are “... rooted in individual consciences and morality; a reflection of our twisted mentalities.”

Although these respective perspectives represent four very different weltanschauungen, they all present the case in one way or another for the idea of “meeting the needs of the present without compromising the ability of future generations to meet their own needs” (22). And implicit in this is recognition that current agricultural practices may have a wide range of negative impacts that are detrimental to the long-term integrity of both the biophysical and sociocultural environments with which they are so intimately interconnected. It is our responsibility as agricultural scientists to ensure that our ways of doing science are sufficiently pluralistic to respect each of these different world views.

Realization of the need for ways of dealing scientifically with such negative externalities is not new nor is the acute awareness of the tension of difference that arises when different ways of conducting science are brought to bear on the same phenomenon. As has been noted

... the disciplines in that [Land Grant] system are characterized by certain fundamental differences in philosophical and methodological posture ... the key axis of this typology is a dichotomization of disciplines according to whether their principal mission is production enhancement (production science) or impact assessment (impact science). (10).

This statement proves a fertile ground for exploration of some of the fundamental philosophical and methodological differences in science that lead to the logic of systemic approaches to agricultural development. So too does the notion of what I might call the “dichotomization trap”, for it lies at the heart of our apparently mindless inability to embrace new paradigms. According to Eileen Langer (41), mindlessness is a psychotic condition in which we respond to situations

... without considering their novel elements and instead, relies on old distinctions rather than creating new categories.

By accepting the duality of dichotomies, we become entrapped in dilemmas of our own creation. In the present context, therefore, mindlessness represents a double jeopardy. As the brief discussion about sustainability revealed, agriculturists must be mindful of avoiding traps set by dualistic differences in the way science is conducted as well as of philosophical issues that conventionally are considered beyond the domain of scientists altogether.

In other words, I posit that we need to address critically the need for a new science of agriculture that embraces both “production enhancement” and “impact assessment” while transcending them both. This is the essence of the paradigm for the new age, and, just as it is appropriate as a science of agriculture, so too must its implications for the sciences in agriculture be established. We need to explore the many philosophical and methodological assumptions in all of the sciences associated with agricultural research that are usually left unexplored, sometimes throughout an entire career!

Any research—and, indeed, extension—related to issues of sustainability and of sustainable improvements in the quality of agricultural systems must include critical philosophical reviews of issues that are ethical and moral as well as those that involve aesthetics. As scientists, we must also explore other philosophical territories concerned with our ontological beliefs about the nature of the world as well as epistemological beliefs about the ways by which we come to know about nature. And finally, there is a host of crucial issues about reason and forms of logic that
need to be investigated if any mindful investigation of new perspectives on agricultural and rural development is to be achieved.

BEYOND THE PRODUCTION-IMPACT DICHOTOMY

The commentary about sustainability reveals the complex, uncertain, and even paradoxical nature of agricultural development in its broader context. A science that must accommodate such dimensions will be profoundly different from both the science of limiting factors and that of negative externalities. Indeed, the very first prerequisite of such a science is that it enables the researcher to escape from the dichotomy trap set by the production-impact duality (or any other for that matter). According to our thesis of mindlessness, this is asking a lot. The approach to finding a common ground between polar opposites is both endemic to Western thinking and its greatest weakness. Consensual strategies are rarely that. The common ground invariably turns out to be the preferred ground of the most powerful contestant while the conflict between the differences remains unaddressed, let alone unresolved.

If ever there was an impediment to innovative thinking, it lies in what has been referred to as "the mutual negation of conflict" (46). To escape being sucked into this dichotomy trap, it is suggested that we need to learn how to "bring forth new worlds together." Robert Pirsig (50) puts it more pungently when he suggests that kicking sand into the bull's eyes is an effective way off the horns of a dilemma! Herein lies the essence of the systemic paradigm—the deliberate intention of the researcher to move to a new ground, or a new order of wholeness if you will, and the readiness that he or she displays to exploit the inherent surprises in so doing! Perhaps the first surprise to agriculturists reared in the production science tradition is that there is no unity of belief about the nature of the world or that one needs different theories of knowledge to explore it fully. Yet as has been posited (53), it is not difficult to take issue on at least six presuppositions of orthodox scientific inquiry and its paradigm of positivism and reductionism: 1) that there is one reality out there; 2) that it can be known objectively; 3) that such knowledge is identical for all knowers; 4) that knowledge is expressed in propositions that are validated empirically (in the ideal form in carefully controlled experiments); 5) that the whole may be explained solely in terms of the sum of its parts and that the aim of inquiry is to discover more and more fundamental elements and processes; and 6) that explanation is sought in terms of linear, energetic cause and effect. For the postpositivist scientist, however,

... whatever nature may be, or however the quest for truth will turn out in the end, the events we face today are as subject to as great a variety of construction as our wits will enable us to contrive. (37).

There is a curious paradox about the way we go about our construing, and it clearly is a manifestation of mindlessness. We operate as if we are paying attention to the details of a given situation and weighing an appropriate, innovative response, when in fact we are not (41). In other words, even when we think we are thinking in a novel way and dealing with unfamiliar issues in unfamiliar ways, invariably we are not. It is so much easier, and thus pervasive, to deal with unfamiliar issues in a familiar way than it is to deal with familiar issues in an unfamiliar way. The irony is that

... human intelligence is the ability to spot patterns of unanticipated types in unanticipated places at unanticipated times in unanticipated media. (52).

THE ESSENCE OF SYSTEMICITY

The systems paradigm is based on the predisposition and competencies of the researcher to seek novel ways of patterning strange experiences as well as seeking novel patterns within those experiences. The framework for both "levels" of patterning lies in the notion of wholeness—of wholes within wholes within wholes: each whole contains a set of interacting subwholes while it is itself a subwhole of a suprawhole. At each change of "level" within this constellation, new surprises lie in store, for unique properties emerge: a phenomenon akin to the surprise of "wetness" of the water born of the union of the gases hydrogen and oxygen. This is as relevant to those concerned with the behavior of subatomic particles as it is for those concerned with the transaction involved in international trade.
As wholeness and emergent properties are both vital dimensions of systemicity, so too are interrelatedness and connectivity. Systems are wholes (or are regarded as wholes) because their parts are connected in such ways that they give rise to a sense of wholeness (65). A unity emerges through the interrelationships of the parts in such a manner that the system is different from the sum of its parts with behaviors that display emergent properties. As every system is both comprised of interacting subsystems as well as being itself a subsystem of a “higher order” suprasystem, all systemic analyses must concern themselves with several different orders of complexity in their methodological procedures.

In “true” systems approaches, then, those that reflect what has been referred to as the systems philosophy (42), both the issues being investigated and the methodologies used in their investigation are systemic. This, in turn, means that the practitioner is perforce a participant in any process of systemic inquiry for... . . . wholeness means that all parts belong together, and that means they partake in each other. Thus from the central idea that all is connected, that each is a part of the whole, comes the idea that each participate in the whole. Thus participation is an implicit aspect of wholeness. (59).

And this concept has profound consequences for the classical lineal model of the generation of technological innovation and its diffusion through transmission and adoption. Can the “pure” scientist ever make an observation that is totally objective? Can the biological or physical or social or economic worlds ever be “truly” known? Can an extension agent ever really transfer a technology? Can an educator ever really teach anyone anything?

Systemic analysis does not concern itself with the lineal logic of causes and effects, nor with problems and solutions, nor with starts and finishes, nor with the unidirectional flow of information from generator, through transmitter, to receiver. Because of the connectivity and interrelatedness of wholes within wholes, systemic analysis is always recursive. This is a difficult concept to grasp even from its formal definition: “...a recursive phenomenon is a product of multi-directional feedback” (51). Rather than accepting “lines” of simple causal relationships, systemic practitioners accept that problematic situations represent many “faces” of a complex “mess” of issues held in networks of mutual influences. It makes much more sense under such circumstances to talk of improving problematic situations rather than solving discrete problems, for one person’s solution is often someone else’s problem. The systemic ideal is for strategies of intervention that lead to improvement to whole systems and to their relationships with their environments.

Systemic thinking can also pose a considerable threat to the experimental scientist who has conventionally been quite content to “control the environment” in the interest of reduced variation. What distortions to “truth” do experiments represent? What sensitive interrelationships are actually shattered in the laboratory in the quest for “truth”?

SYSTEMS PRACTICE

The first step in systems practice, as has already been intimated, is to escape the “trap” of dichotomization. For the systemic practitioner, it is not a matter of consensus or trade-offs between apparently polarized positions, but an analysis of the patterns that emerge when the reasons for the distinctions between them are explored as if they were different faces of the same reality. From this perspective, agricultural production, for instance, is not viewed as a process in opposition to environmental conservation but as an issue of it. The systemic agriculturist accepts that there are many opportunities for developments that represent improvements to the whole situation and that are immanent among the relationships that exist between farmers and their environments. It is a matter of designing and utilizing appropriate systems of inquiry that will reveal them to all of the participants involved in the situation. It is not that the apparent dichotomy is ignored but rather that the different perspectives are explored in novel ways where the dialectic tension that exists between apparently opposing views is used as a trigger to “bring forth new worlds together”. Of course it is also quite possible to “escape the horns of the dilemma by kicking sand in the bull’s eyes” and come at the issue of food production, farmer welfare, and environmental integrity from quite a different integrated perspective altogether.
In any event, the key focus of such an approach will be concentrated on what Peter Checkland (13) recognizes as “debates about desirable and feasible changes.” It is in this context that it can be claimed that

... the most important feature of the systems approach is that it is committed to ascertaining not simply whether the decision maker’s choices lead to his desired ends, but whether they lead to ends which are ethically defensible. (16).

The systemic thinking and practices that will be involved in situations like this will recognize the advantages of embracing the spiritual with the conceptual, perceptions with conceptions, passions with reason, integrated wholes with isolated parts, intuition with critical thought, the concrete with the abstract, subjectivity with objectivity, the qualitative with the quantitative, science with philosophy, and of course, theory with practice. Systemic practitioners, be they “pure” scientists or “applied”, researchers or extensionists, will not view these as dualities—as pairs of polar opposites—but as different aspects of the same phenomenon with neither aspect being prime over the other. It is in the integration of each with the other in the process of patterning where each informs the other that the synergy implicit in the “glorious unity of opposites” (64) can be exploited.

A CERTAIN LOGIC

Clearly, the simple reasoning of induction and deduction upon which positivist reductionism is based is quite inadequate in the face of all of these interconnected dimensions of systemic inquiry. Gregory Bateson (2) has suggested an alternative in abduction: abductive logic proceeds through metaphor and analog—this is to this as that is to that—and our daily conversations are replete with examples even if, in the majority of cases, we are quite oblivious to them. This calf looks just like her dam. This sunset reminds me of summer evenings in Vermont. This seems like the same situation we faced in last year’s markets. I have a feeling that it is going to rain again. And so on.

Actually, this last example has the essence of what Kathleen Forsythe (26) has referred to as isophor. Where “...metaphor is understanding one thing in terms of another ... isophor is experiencing one thing in terms of another”. Thus, isophor is the way the sense of wholeness is grasped in any set of relationships be they between people or between people and their environments. In this instance, it is the systems metaphor that allows us to understand the pattern of such relationships as systemic. The usefulness of abductive reasoning in exploring complex relationships comes through the notion of searching for “similarities in patterns across seemingly disparate phenomena,” (59) including the process of patterning itself, as previously emphasized.

There is a final distinction that I must make here because it is a vital element in the confusion that continues to plague the systems movement at large and its applications in agriculture specifically. Essentially, the systems movement has been born of two quite different intellectual traditions, and the resulting distinctions in methodological approaches reflect these. As Checkland (15) has suggested, the word system is used to describe ontological realities as they are accepted as existing in the “real” world—a farm is a system, in this language. But the word “system” has also been used as an epistemological device for knowing about the world, and here it is that the issues associated with the farm are thought about as if they were interrelated in some way or another. The distinction is often made between hard systems approaches and soft systems approaches to discriminate between these two traditions. In order to highlight the foundations from which each of these approaches is developed, I now propose that as philosophical traditions, they might be renamed “ontosystemics” and “episystemics”, respectively.

In the former approach, analysis usually proceeds from the two questions. Which system is being investigated, e.g., what is the ecology of a particular dairy farm? What constitutes an improvement to its performance? In the latter approach, the leading questions follow a different logic: in this messy and complex situation, which is somehow or another associated with dairying, what seem to be the issues that people perceive as problematic? How can systems of inquiry (systemic thinking and practices) be used to explore and eventually improve them? This form of inquiry, as indicated earlier, is participative. Because it
involves abstract interrelationships between the issues being explored and those doing the exploration, we might refer to this phenomenon as an ecology of mind, to follow an idea of Bateson (2). This change in awareness from the ecology of a farm to that of an ecology of minds that are exploring issues associated with the functioning of that farm represents what has been described as "...the shift in systemicity from reality to the process of inquiry into reality" (14). This vital distinction is regrettably rarely made in the ever increasing literature appearing under the rubric of Systems Approaches to Agriculture and Natural Resource Management.

AGRICULTURAL SYSTEMS AND SYSTEMS AGRICULTURE

The situation with regard to different systems approaches to agricultural development is confused, basically because most of them are born of the ontosystemic tradition without that being made explicit. Perhaps what is more serious in adding to the confusion is the fact that much of the literature on agricultural systems has little to do with the essence of wholeness or with the exploration of the surprises inherent in emergent properties. Furthermore, in much of the so-labeled research into agricultural or farming or cropping systems or even agro-ecosystems, the farmer client is anything but a participant in the research process. Neither is situation improvement nor the behavior of construed systems in their environments the typical focus of the research.

I might use the new categories I have created to explore these submissions. 1) Ontosystemic inquiry is concerned with the study of things as systems as they exist in the world. Farming systems research and agro-ecosystems analysis are prime examples of this approach. 2) Episystemic inquiry is concerned "not with an external reality but on people's perceptions of reality, on their mental processes rather than on the objects of those processes" (13). Systems Agriculture, as developed at Hawkesbury College at the University of Western Sydney in Australia, is an example of where such an approach is embraced as an important method of establishing the domain of, and the subsequent exploration of, improvements to messy and complex problematic situations.

The critique that follows is not intended in any way to present a comprehensive critical review of the field. Rather, its purpose is merely to highlight some of the issues and provide a bibliographic access to further developments of respective themes. It will also enable the proposed distinction between episystemics and ontosystemics to be further explored.

FARMING SYSTEMS PERSPECTIVE

It has recently been claimed that the farming systems research (FSR) paradigm has become distorted by its connection by association with "any research that does not fall within the conventional, institutional, categories of commodity or disciplinary research" (56). The original axioms of FSR were quite straightforward: 1) that the development of relevant and viable technology must be grounded in a full knowledge of the existing farming system; and 2) that technology should be evaluated not solely in terms of its technical performance but in terms of its conformity to the goals, needs, and socioeconomic circumstances of the targeted small-farm system as well. Now, however, the FSR movement has become so eclectic that the term FSR perspective has been introduced as a more suitable term for the generic concept (11). Fresco (28) has classified FSR into the two major strands of anglophone and francophone; the latter is more akin to long-term land utilization, and the former is concerned more with incremental changes in traditional farming systems. Others have suggested that this is an insufficient typology. Sands (56), for example, has proposed that within the perspective, the following six, more precisely defined areas of research activity can be recognized: 1) farming systems analysis; 2) farming systems adaptive research; 3) farming systems component research; 4) farming systems baseline data analysis; 5) new farming systems development; and 6) farming systems research and agricultural development, although these categories also embrace the three categories suggested by Simmonds (58); 1) FSR in the strictest sense, 2) on-farm research, and 3) new farming systems developments.

The variations among these approaches to agricultural research and development that justify their discrimination lie in the areas of
research intent, the extent of farmer participation and the role of on-farm experimentation, the degree of innovativeness involved, and the extent of the involvement by researchers from different scientific disciplines. Common to all, however, is the ontosystemic logic that sets the two guiding questions of the perspective. What is the nature of the agricultural system under study? How can its performance be optimized through technological innovation?

The primary objective of all of these farming research approaches is to increase the productivity of small farms, and central to their framework is the ontosystemic concept of the farm as a purposeful system:

A unique and reasonably stable arrangement of farming enterprises that the household manages according to well-defined practices in response to physical, biological and socio-economic environments and in accordance with the household’s goals, preferences and resources. (57).

The point has been made (49) that the foundation of FSR was really pragmatic rather than theoretical or philosophical with an emphasis on research to increase the production of marketable crops. In spite of this emphasis and particularly given the prominence of FSR through its role in the International Agricultural Research Centers, it is perhaps surprising not to find a rigorous conceptualization of just what it is that constitutes an agricultural or farming system. Those models that exist do not extend much beyond descriptions of sets of relationships between enterprises and the household.

One fairly abstract model that betrays the strong influence that farm management economists have had on the development of FSR is provided by Dillon (21). He proposes that the farm as a purposeful system includes the following subsystems: 1) technical; 2) formal structural; 3) psychological or informal structural; 4) goals and values; and 5) managerial. This would place FSR in the general systems typology (15) as a “designed physical system”, which exists by virtue of some “human purpose which is their origin” and to serve a purpose even though this “may be hard to define explicitly”. The multitude of purposes that Ruth Gasson suggested can be identified with farming (29) adds particular poignancy to this last comment.

Other workers have developed an interesting perspective for farming systems by integrating farm management foundations with ecological ones. Models such as these have facilitated the incorporation of quantitative tools such as mathematical modeling, computer simulation, and optimization techniques (31, 49). As has been claimed (31, 48), there is a plethora of materials now available about quantitative models for both biological and socioeconomic systems. Indeed, work in this area has been so prolific that many see quantitative models as the foundation of the FSR perspective. The sophistication of expert systems and their application to agriculture is now enhancing this view, and a useful set of distinctions has recently been proposed to characterize the increasing variety of approaches in this domain (36). 1) Heuristic expert systems come closest to the sort of “seat of the pants” decision-making strategies used by recognized experts; 2) real time expert controls are decision tables used with sensor data in cybernetic networks; 3) model-based expert systems link simulation models and expert systems; 4) expert data bases such as the national DHIA use expert systems to facilitate information searches; and 5) problem-specific skills enhance the application of expert systems concepts to agricultural problems.

It would be accurate to treat expert systems as passive knowledge systems rather than as knowing or learning systems. It would also be accurate to present farming systems as researched rather than researching systems. There are those that argue that farming systems approaches are more systematic than systemic (4, 33) and it has been even posited that the problematic characters of FSR, as it is actually conceived, is scarcely discerned and that a critical approach to study and to developing farming systems has hardly been developed. (8).

AGRO-ECOSYSTEM ANALYSIS

If the foundations of the FSR perspective were a mixture of farm management practices and theories, tinged with an ecological perspective, agro-ecosystem analysis and development is unashamedly ecological. As has been pointed out (44), the concept of the agro-ecosystem as a managed “natural” system has provided a focus for many research studies
over the years. It has also acted as a vehicle for educational strategies. However, as Conway (19) suggests, most of these initiatives have tended to concentrate on analysis of flows and cycles of energy and matter and have thus "had little impact on the theory and practice of agricultural development."

In Conway's own work, the concept of the agro-ecosystem is given a different and powerful reorientation through its presentation as a cybernetic, self-regulating system. He provides an interesting if moot perspective on the "true" ontological status of systems by positing that there can be little doubt that the transformation of ecosystem to agro-ecosystem produces well-defined systems of cybernetic nature.

In this way he neatly side steps the controversy regarding the actual nature of 'natural' ecosystems (23, 61, 64).

It has been suggested (18, 45) that the essential behavior of agro-ecosystems can be described by examination of the five systems properties of: productivity, stability, sustainability, equitability, and autonomy. Given the clear exposition of the hierarchical nature of agro-ecosystems, the claim that these are indeed emergent properties can be, at least conceptually, readily accepted. However, others (5) reviewing the agro-ecosystem approach conclude that while the properties are useful guides to improvements in agriculture, each is replete with ambiguity of meaning. This is exemplified for instance by the work of Kingma (38) on productivity and Douglass (22) on sustainability.

SYSTEMS AGRICULTURE

The final approach reviewed comes out of a quite different intellectual tradition compared with the onto-systems of FSR and agro-ecosystem analysis and development. Systems agriculture was born of an episystemic tradition drawing heavily on learning theory, systems philosophy, and soft systems methodology for its foundations (6). Following Checkland (15), the attempt has been to shift the systemicity from the reality being observed (from a focus on agricultural systems as ontological realities) to the process of observing the reality (and the episystemicity of systems of inquiry). The work of C. West Churchman (16), Peter Checkland (15) and Gregory Bateson (2) has been particularly influential on systemic methodology, and Jerome Bruner (9), David Kolb (39), Kurt Lewin (43), Carl Rogers (54), and Peter Reason (52) have all contributed greatly to the learning methodologies. The essence of the Hawkesbury systems agriculture approach is the notion of the creation of "action researching systems" (3) in which people collaborate together to explore complex problematic situations critically with the aim of creating change that is socially desirable, culturally feasible, and ethically defensible. It demands the integrated use of a plurality of methodologies and also explicit discussion of philosophical positions appropriate to each such system of inquiry whenever it is used. In such an ecology of minds, traditional roles—researcher, extensionist, educator, client—become obscured. All behave as active inquirers with each assisting the others as part of an integrated system of inquiry.

One of the emergent properties of the inquiry system itself—one of the great "surprises" it represents—is the notion of learning as transcendental to the classical trinity of activities of research, education, and extension. Knowledge is not a commodity to be transmitted as a set of propositions or practical competencies. It is rather to be created experientially as the transformation of personal experiences. Farmers or "problematic situation owners" are not viewed as passive receivers of expert knowledge, for under such circumstances, they cannot learn. As Freire (27) saw it, knowledge transfer models condemn the receivers to being "domesticated":

The person who is filled by another with contents whose meaning she or he is not aware of, which contradicts her or his way of viewing the world, cannot learn because she or he is not challenged.

Ways of knowing and knowledge from the context of participative learning—of collaborative inquiry through action researching systems—are empowering with the potential for the emancipation of those who were previously the victims of their ignorance. The active involvement of people in rural areas, working together to explore systemically and improve the complex problematic situations they experience, in such a way that leads to their emancipation and the development of improved...
quality of key relationships between them and their environments, is the ideal to which the Hawkesbury systems agriculture paradigm aspires. Improvements come about as a result of all the participants exploring "unanticipated patterns in unanticipated ways," but all from a framework that respects interconnectedness and the sense of wholeness. All of these collaborators benefit as much from new ways of knowing as from new knowledge. The overarching methodology of systems agriculture is modified from that of Checkland's soft system approach (13), as it provides the context in which other methodologies, both systemic and reductionist, can then be applied.

Cognizance is taken of the critiques of the soft systems approach (25, 55), particularly as it relates to its inherent functionalism (58), its idealism (22), the lack of attention to ethical dimensions (1), and issues of power relationships (16, 24). Following the ideas of Jurgen Habermas (30), Werner Ulrich (62), and Michael Jackson (34), attempts are now being made to incorporate aspects of "critical theory and heuristics" into the approach. The central aim of this dimension is to shift the purpose of the approach from one of regulation to one of empowerment and emancipation based on collaborative learning.

CONCLUSION

As what we do in the world is function of the way we see it, there is a drastic need for us to change the way we go about our seeing as a prelude for fundamental shifts in the way we do things. The central thesis of this paper is that the complexity, dynamics, and even chaos of contemporary agriculture deserves to be treated as such. New ways of "seeing" the world—of perceiving it and making sense of those perceptions as a basis for informed emancipating actions—can be found within the epistemic tradition.

The philosophies in which this tradition is grounded are as eclectic as they are unconventional. The perspective and even practices will be similarly different from classical agricultural research at all levels, from the biological and physical sciences in agriculture to new transdisciplinary science of agriculture.

It is argued herein that unless we, as agriculturists, accept a shift in our thinking and practices appropriate to the magnitude of a new paradigm, agriculture and the environments in which it is practiced will be pulled into an ever declining involution with catastrophic effects on the well being of mankind and of the environments in which we all live.

The systemic paradigm calls for us to rethink our views of our world (and of the way its interrelated components are patterned) as well as our ways of going about the way we view our world. If this rethinking is to lead to the sort of innovative and regenerative processes leading to large-scale improvements in the quality of relationships between people and their environments, it must come from a belief that new ways of knowing are crucial to produce new knowledge.

As agricultural scientists, we must be prepared to question critically our beliefs about what we really think constitutes improvements to agriculture. We must also be prepared to enter into debates about what should be as well as creating visions about what could be. Our focus must extend beyond what is effective and efficient to embrace the ethical. We must be prepared to state what we think is good and what we think is bad, and we certainly must be ready to discuss what is aesthetically acceptable and what is not.

Recursiveness and abductive logic must become as familiar to us as lineal thought and induction and deduction have been for a century and a half. And in our rethinking, we must learn how to come to terms with complexity and chaos and develop learning strategies that enable us to help others to deal with such dimensions. In sum, we must be prepared to let go the old and embrace the new science and praxis of complexity.

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