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Putting Food Production in Context: Toward a Postmechanistic Agricultural Ethic

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Agriculture is a defining characteristic of human civilization. Its development as a means of providing sustenance marked the transition from a nomadic existence to an urban lifestyle. And no other human activity has transformed so much of the earth's surface as farming (Vitousek et al. 1997). Oddly, the amount of attention given to the underlying values of agriculture is inversely proportionate to the environmental impact of agricultural activity. In academia, two disciplines obviously relevant to agriculture—agronomy and environmental philosophy—have addressed the effects of pesticides and soil erosion or the value of wilderness as compared with that of cultivated land but have not evaluated the fundamental assumptions implicit in the practice of agriculture. Even more surprising, dialogue between agronomists and philosophers is rare.

The metaphysics of industrial agriculture

Any ethic presupposes a metaphysical foundation (Keller 1997). The code of ethics developed by contemporary industrial agriculture rests upon a conception of nature based on the mechanistic worldview that has increasingly defined modern Western science since the Renaissance. The hallmark of this perspective, as expounded by numerous scientists, philosophers, and theologians, is that nature is a grand and exquisite machine operating by the deterministic laws of physics. The astronomer Johannes Kepler first applied this thinking to the heavens. "My aim," he said, "is to show that the celestial machine is to be likened not to a divine organism but rather to a clockwork" (Oelschlaeger 1991)—a view shared by Galileo, Hobbes, Descartes, Newton, and others. Derivative of the mechanical view of nature is the belief that natural systems are understandable, predictable, and manipulatable. Indeed, the social responsibility of science is often couched in terms of prediction and manipulation, and adherents to the mechanical view tend to be optimistic about achieving these goals.

Connected with the metaphysics of mechanism is the idea that nature, as machine, has no intrinsic value. This axiology of nature is manifested in Western religion, philosophy, and science. Whereas paganism held the earth to be sacred, Christianity increasingly held it to be profane and subject to man's desires: "And the Lord God took the man, and put him into the garden of Eden to dress it and to keep it" (Genesis 2:15). For pre-Christian pagans, economic activities such as plowing or mining were barred on religious grounds, to prevent cutting or digging into Mother Earth (Jackson 1987, Merchant 1990). The shift in religious worldview about the ontology of the natural order was synchronous with expanding economic exploitation of natural resources (White 1967), as lamented by the Roman poet Ovid (Figure 1; trans. Mandelbaum [1993]) in the *Metamorphoses*:

And now the ground,
which once—just like the sunlight and the air—
had been a common good, one all could share,
was marked and measured by the keen surveyor—
he drew long confines, the boundaries.
Not only did men ask of earth its wealth,
its harvest crops and foods that nourish us,
they also delved into the bowels of earth:
there they began to dig for what was hid
deep underground beside the shades of Styx.

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In science and philosophy, the mechanistic view maintains that only quantifiable (or primary) properties—namely, the parameters of classical physics such as size, shape, speed, mass, distance, and time—belong to the natural order. Qualitative (or secondary) properties—such as the taste, smell, sight, and touch of Descartes’s piece of wax ([1641] 1989), Hobbes’ “phantasms” ([1651] 1985), or the blue color and sweet scent of Locke’s violet ([1690] 1985)—emanate from human consciousness. In and of itself, then, brute nature is absolutely devoid of qualitative value.

Consistent with—but not necessarily logically derivative of—mechanistic metaphysics is the epistemological doctrine of the fact–value (or is–ought) gap. Inspired by David Hume’s ([1740] 1992) observation about the propensity of many thinkers to derive value-laden prescriptions from value-free descriptions, many scientists and philosophers have asserted the existence of an insurmountable gap between science and ethics. As the English philosopher Bertrand Russell (1961) remarked, “[Q]uestions as to ‘values’ lie wholly outside the domain of knowledge. That is to say, when we assert that this or that has ‘value,’ we are giving expression to our own emotions, not to a fact.” Using this line of reasoning, one can garner facts independent of values. A clear example of this type of thinking occurred during the Manhattan Project, when scientists developing the atomic bomb adopted the view that they were to focus only on nuclear physics without making value judgments about the practice of detonating nuclear devices. (One of the scientists, J. Robert Oppenheimer, later renounced his dedication to the fact–value gap, telling President Truman he felt as though he had “blood on his hands” [Kunetka 1982].)

The implications of mechanistic metaphysics and the fact–value gap for the practicing farmer, the agribusinessman, and the agricultural scientist are profound. English philosopher John Locke ([1689] 1996) persuasively argued that nature itself has no inherent value, but that human beings, through labor, can transform the latent extrinsic (or resource value) of land into useful products. Thus, the mechanistic view of nature promulgates an economic model of human–nature interactions. The farmer is to produce as much food as possible, and neither the producer nor the consumer should make value judgments about the noneconomic worth of the land. After all, values are epiphenomena of human subjectivity and human activity; they are not embedded in the land.

Agriculture and the production paradigm

Modern agriculture has become highly industrialized in order to reliably produce the largest amount of plant and animal product possible while minimizing labor inputs. Through the incorporation of numerous components manufactured externally to the farm, including fertilizers, pesticides, and technology, the modern system manipulates the land to make it amenable to industrial processes. Typically, crops are produced as large-hectare monocultures consisting of a single genotype planted across an entire field (Figure 2). Most farms using modern agricultural methods cultivate only a few crops



Figure 1. From *Agricola* ([1556] 1912).

grown in simple rotations such as wheat–fallow or maize–soybean. Similarly, most animals are grown in feedlots or climate-controlled buildings in order to closely monitor feed efficiency and to guarantee uniform meat, egg, or milk products. Cycling of nutrients is not a major consideration of most industrial agricultural systems because the addition of externally derived fertilizers is cheaper and simpler than collecting, storing, and using manure.

Under the production paradigm, the prime directive is to improve the productivity of a select set of plants and animals. Solutions for problems arising in the system are discovered through scientific research leading to the development, production, and implementation of new technology. Finding these solutions can be expensive, but molecular biological advances, such as the sequencing of the genome of the model plant *Arabidopsis thaliana* (Arabidopsis Genome Initiative 2000) and the development of large-scale gene exploration methods (Somerville and Somerville 1999), promise to supply solutions to a host of genetically based problems more easily, more quickly, and more simply than currently available methods permit (Briggs 1998, Chory et al. 2000).

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Figure 2. The increasing industrialization and decreasing diversity in farming in the latter half of the 20th century is shown in this comparison between an aerial photograph of a 9-square-mile section of Humboldt County, Iowa, taken in 1953 (left) showing substantial diversity of crops in small fields on many farms, and the cropping sequence in 1999 (right), which shows only maize (corn, C) and soybean (B) crops and many farms that are either no longer present or no longer involved with farming operations, as designated with an X. Aerial photograph from Lee Burras.

Therefore, at the heart of the production paradigm is the realization of the greatest possible quantity of agricultural product. Other factors, such as ecological or aesthetic values of the agroecosystem, receive scant attention outside limited areas within academia, as can be easily visualized by driving through the corn or wheat belts of the United States.

Ecological shortfalls of the production paradigm

Simplified systems of modern, industrial agriculture bear little resemblance to highly complex natural ecosystems. Within natural ecosystems, various biotic and abiotic components form an intricate network of interactions, allowing the systems to be both functional and adaptive under a wide range of conditions (Hulot et al. 2000, Williams and Martinez 2000). These ecosystems provide many services to the biosphere and hence to human survival and enjoyment (Balvanera et al. 2001). The value of these ecosystem services is considerable (Costanza et al. 1997), although as David Ehrenfeld remarked, “I am afraid that I do not see much hope for a civilization so stupid that it demands a quantitative estimate of the value of its own umbilical cord” (Stevens 1997). Agricultural systems based on the production paradigm do not recognize these hard-to-quantify, yet ecologically important, values. Although the structure, functioning, and values of natural systems could provide important clues about developing sustainable agricultural systems (Tilman 1999), little effort is devoted to investigating them.

Complex natural systems often exhibit emergent properties, characteristics that are not predictable from an analysis of the system’s components (Odum 1986), such as stability in the face of perturbation. Because these properties are absent from simplified modern agricultural systems that lack important components present in natural systems, the rationale of developing such systems has been repeatedly questioned (Drinkwater et al. 1998, Matson et al. 1997, Tilman 1999). Critics outside the academic scientific community, such as Wendell Berry, Wes Jackson, and others, have made particularly pointed attacks on the insular, noncritical agricultural research community, which has focused most of its resources on the promulgation of the production paradigm. In rebuttals to these critiques, production-oriented proponents argue that the appropriate course of action is to modify existing systems toward increased sustainability (Sinclair and Cassman 1999). Consequently, a never-ending stream of new technologies, including pesticides and herbicides, chemical fertilizers, genetically engineered crops, and precision machinery, has been developed and applied (Lewis et al. 1997). Even though these modifications have not resulted in sustainable systems, it is hoped they eventually will.

Thus, the design of agricultural systems is based on commodity production and its attendant economics; the importance of modeling farming systems after natural systems, based on ecological principles, is widely overlooked. The American ecologist Aldo Leopold named the schism between the economic and ecological models of farming the “A–B

cleavage” (Leopold [1949] 1987). The economic model (A) considers the value of the land to be its resource or productive potential, as espoused by Locke ([1689] 1996). Conversely, the ecological model (B) considers the land to be a living thing, including not only soil but also the plants and animals living in and on it and the water and energy flowing through it. In model (B), ecosystem components have types of value above and beyond direct economic value alone. The production paradigm of current agricultural systems clearly espouses model (A). Some adherents of the production paradigm reject outright the values suggested in model (B); others admit their existence but consider them only to the extent that they do not interfere with production of agricultural commodities.

From an ecological perspective, however, the productionist program fails doubly: It does not consider positive ecological benefits that could arise through different farming system architectures—increasing migratory bird habitat by restoring drained wetlands, for example—but it externalizes many costs associated with current production practices. An externality is a consequence—favorable or unfavorable—of an activity for which those affected by the activity are not compensated (Samuelson 1980). Because they are hard to track and tabulate, economists often lump together such consequences in cost-benefit analyses and label them externalities. Despite

the dual character of externalities, the term has become a euphemism in economics and politics for masking the negative environmental consequences of public policy decisions regarding agricultural and other practices. As suggested above, many factors relating to the ontology of agroecological systems are not amenable to quantification. The severing of links in food webs by biocides, pollution related to soil erosion (Figure 3) and the use of fertilizers, and the reduction of biodiversity are often written off as externalities and excluded in the decisionmaking process about prudent agricultural policy. In the estimation of American philosopher Paul Thompson (1995),

Productionism is an absurd philosophical position on the face of it. It is contradicted by the oldest of old saws: man does not live by bread alone. There are no sophisticated philosophical defenses of productionism. Arguably, no individual has ever believed in it. Statements of the productionist norm must be found in slogans or aphorism, such as [Nixon administration secretary of agriculture] Earl Butz’s injunctions to “plant fencerow to fencerow,” and to “get big or get out.”

Yet we continue to conduct agricultural research, business, and practice as if productivity were the ultimate goal. Current high-yield agriculture and its attendant modern technologies are justified not on ecological grounds but by claiming to be the only means to feed the world’s growing population (Thompson 1995, Briggs 1998). Since industrial agri-



Figure 3. Erosion on industrially farmed landscapes can be extensive, as exemplified by these photographs taken in Boone County, Iowa, in the late 1990s. Wintertime wind erosion from row crop fields causes “black snow” in the ditches (top left); no soil is blown off a rare, neighboring pasture (top right). Water (lower left) and wind erosion (lower right) from newly seeded soybean fields does not occur in the oat–alfalfa intercrop in the foreground of the lower right photograph, which was seeded approximately 2 months before the soybeans.

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culture significantly benefits the corporations selling the technologies deemed essential to “feeding the world,” we may rightly question the validity and sincerity of such claims. Currently, Western countries produce so much of some commodities, such as maize and soybeans, that prices are at historically low levels, necessitating governmental intervention to avoid bankrupting farmers. In the United States, both land grant universities and the USDA Agricultural Research Service routinely hire scientists to find alternate uses for these crops. Therefore, the current need in the West is not increased production. That starving people live in a world with abundant food suggests that “what is missing is the ‘purchasing power’ of the poor” (Latham 2000). The imperative of “feeding the world” through industrial agriculture is a dogma with little foundation.

In 1962, Rachel Carson (1994) decried the “arrogance” of thinking pesticides (or more accurately, biocides) could control nature. Despite 40 years of trying, we are still incapable of controlling even (or perhaps especially) the simplest agroecosystems: Weeds, insects, pathogens, and nematodes continue to exact an immense toll in money and labor from our agricultural enterprise. If the system that we use to produce food does so in an environmentally unsound—that is, unsustainable—manner, then no matter how much it produces now, it will produce far less in the future, when the world’s population very well might need it. Clearly, the development of stable and sustainable agricultural systems is needed first and foremost. The huge food surpluses that currently exist give us a remarkable chance to explore other avenues toward the dual goals of productivity and sustainability.

Fertile ground for the 21st century: Postmechanistic agriculture ethics

We have argued that (a) modern agricultural practice has evolved from the mechanistic worldview dominating modern science, (b) current technique involves the simplification, homogenization, and manipulation of agroecosystems, and (c) these systems are ecologically unsound and unsustainable. We would add that (d) rethinking agricultural practice within a postmechanistic—rather than a mechanistic—framework provides the basis for the development, maintenance, and improvement of sustainable agroecosystems.

The history of the hegemony of mechanism in the Western intellectual tradition suggests the need for a new metaphysics (Whitehead [1925] 1967). To this end, the word *postmechanistic* may be used to describe the rejection of the purely mechanical view of nature. In science, postmechanism involves the adoption of an indeterministic, stochastic view of nature, exemplified in physics by Heisenberg’s uncertainty principle. In philosophy, postmechanism involves the elaboration of an “organismic” metaphysics and axiology (Whitehead [1929] 1978, Ferré 1996). The implications for ethics of rejecting the mechanistic view of nature, closing the fact–value gap, and recognizing that nature is imbued with value are that moral decisions ought to be taken in context: ecology entails ethics (Keller and Golley 2000).

A postmechanistic agricultural ethic does not suggest that mechanism is not important in improving agricultural systems. Just as Newtonian mechanics continues to be useful at explaining many physical phenomena despite the development of quantum mechanics, mechanistic investigations and explanations are still relevant to a postmechanistic agriculture. With respect to a postmechanistic ethic, we contend that the methods used to mechanistically dissect agriculture and its components need to be revised (as described below) and that nonmechanistic aspects of agricultural systems—ecological and qualitative values—need to be given consideration when constructing sustainable systems. Postmechanism is relevant to agriculture because it lays the groundwork for a more sustainable agricultural practice in at least five ways.

First, agricultural science and practice must become context-sensitive and holistic in methodology. Reductive techniques, exemplified by modern genetics and molecular biology, have resulted in substantial improvements in our understanding of the natural world. Yet, they need to be balanced with synthesis—namely, consideration of the unique ecological relationships of biota to each other and to the nonbiotic environment intrinsic to each agricultural system. It is unlikely that we will soon understand the mechanics of any plant or animal, given the complex interactions of the component parts of each one, let alone the myriad stochastic factors inherent in an agroecosystem.

Living systems are machinelike in many respects, but they cannot be understood solely in terms of deterministic and predictable cause-and-effect relationships (Rosen 1991). Biologist Richard Lewontin (2000) suggested that metaphors are useful and necessary, but that “there is a great risk of confusing the metaphor with the thing of real interest. We cease to see the world as if it were like a machine and take it to be a machine.” Nevertheless, the nature-as-machine view is still popular with biologists:

In order to most efficiently and safely manipulate plants to meet growing societal needs, we must create a wiring diagram of a plant through its entire life cycle: from germinating seed to production of the next generation of seeds in mature flowers.... The ultimate expression of our goal is nothing short of a virtual plant which one could observe growing on a computer screen, stopping this process at any point in that development, and with the click of a computer mouse, accessing all the genetic information expressed in any organ or cell under a variety of environmental conditions (Chory et al. 2000).

The fact that a plant of a given genetic constitution develops differently across environmental conditions disabuses botanists of the very hope of completely understanding its developmental trajectory, simply because the environment is continuously changing in unpredictable ways.

The agroecosystem includes endemic micro- and macroflora and fauna, the micro- and macroclimate, and the soil, all of which affect the growth and development of crop plants. Although some aspects of agroecosystems are deterministic and predictable, significant, and perhaps insurmountable, gaps remain in our understanding of biology across hierarchical levels from the gene to the landscape.

Therefore, agricultural research and the activity of farming must be gauged in terms of the unique ecological conditions of each locale. Folk wisdom, often unwelcome in academic journals, is revalidated when this approach is used. The consequence of context-dependent agriculture is that universal farming principles are not achievable. The same industrial equipment, the same chemicals, and the same seeds will not be equally effective in diverse locations.

Second, the role of diversity in agroecosystems must be considered (Brummer 1998). In some instances, increased diversity has been shown to have positive effects at various ecological scales. For example, complex landscapes improve biological control of pests (Thies and Tscharrnke 1999), diverse mixtures of crops promote effective nutrient cycling (Drinkwater et al. 1998), species diversity improves biomass productivity and stability (Tilman et al. 2001), and genetic diversity within fields decreases disease pressure (Zhu et al. 2000). These examples suggest that biological diversity buffers the agroecosystem against perturbation. Thus many species that are not recognizably important on the economic model (A) function indirectly in the production of crops. Other research has indicated that the relationships among diversity, productivity, and stability are not clear, and examples contrary to those listed above may be found in the ecological literature. This conflicting literature suggests that the important point is that the relationships are context dependent—what works in one situation may not work on another—and we must become more attuned to this reality. While the exact relationships between ecological diversity and stability remains controversial, diversity is a major indicator of the health and well-being of a biotic community (Golley 1998) and provides an important hedge for food stability against the vagaries of uncontrollable factors. This argues that a total systems approach to agricultural sustainability is needed (Lewis et al. 1997).

Third, technology may not offer the solution for all agricultural problems. Agricultural science currently exists in the modern, Panglossian world where no hurdle cannot be overcome with more money, more study, and increased technological implementation. Although technology itself is not necessarily a problem, we have been deploying ever more expensive “magic bullets” to solve emerging agricultural problems; that they inevitably become ineffectual strongly suggests that the structure of our current systems is not sufficiently robust to encompass both high productivity and environmental sustainability. Overlooked by the current mechanistic approach are simple alternatives, such as crop management methods based on genetic or species diversity, that produce a more complex agroecosystem, an emergent property of which could be elimination of some previously intractable problems. A recent report demonstrating that rice mixtures grown across thousands of hectares in China had a superior ability to withstand blast infection compared to monocultures supports this possibility (Zhu et al. 2000). By working in conjunction with crop management and ecosystem-scale research efforts rather than in isolation, plant improvement research can devote greater emphasis to the more important

goals of increasing yield and nutritional quality of an entire cropping system (Serageldin 1999).

Ultimately, we can either attempt to impose order into agricultural systems through large-scale external inputs (and a creative accounting of costs), or we can bring order to the agroecosystem by mimicking natural ecosystems and taking advantage of the complexity inherent in them. Constructing plants, animals, and entire agroecosystems by reducing each to its components and then assembling agricultural systems “from first principles” (Somerville and Somerville 1999) does not allow for the expression of emergent solutions to the problems that will confront these systems when they are deployed in the real world.

Fourth, all externalities of agricultural activity ought to be included in cost-benefit analyses when comparing alternate methodologies. Unmitigated market forces invariably lead to undesirable consequences (prostitution, trafficking in addictive drugs, bribery, nepotism, monopolization, to name a few). Agriculture is no exception. The current system appears economically sensible because many costs—such as those associated with soil erosion, nitrogen and pesticide pollution, depletion of aesthetic value by monocultures and factory farms, and diminution of rural communities—are not included. The prescription for this axiological myopia involves legal changes that require the inclusion of externalities in public policy debates about agricultural practice. Once these externalities are considered, alternatives to industrial agriculture may appear significantly more cost-effective.

Fifth, and finally, the preceding points lead to the conclusion that a plurality of methods is desperately needed in agriculture. The techniques of industrial agriculture are treated as sacrosanct: Plant biology, and indeed agricultural science in general, do not stand for criticism, or even for ideas opposed to the dominant paradigm. Writer and farmer Wendell Berry summarized the situation clearly: “Why should our universities sponsor an active criticism of the fine arts...but no criticism of farming or forestry or mining or manufacturing? This question, of course, can be answered by a crude evolutionism—those who survive do not bite the corporations that feed them—but it ought to give some anxiety to a conservationist” (Berry 2000).

A sustainable agriculture cannot be attained by adopting a single farming system, industrial or otherwise, or by ignoring important values associated with the system we choose. Instead, a sustainable agriculture will arise through an aggregation of systems, each adapted to a particular region, to particular farmers, and to particular purposes. This panoply of farming options cannot be easily commodified or industrialized. Land grant and governmental research institutions primarily promulgate the industrial paradigm. Admittedly, some improvements have been made to industrialized systems. The incorporation of integrated pest management strategies and conservation tillage have lessened the environmental impact of farming to a degree. But numerous alternatives—including completely organic systems and perennialized landscapes—that could lead to sustainability of both farms and

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rural communities have received little attention relative to industrialized agriculture. The current industrialized system may be the one best suited to particular situations, but without more effort, little possibility exists that improvements outside the current paradigm can be developed. Land grant institutions can and should facilitate methodological pluralism.

The key to the successful development of a sustainable agriculture requires vigorous debate among all interested parties, with multiple points of view aired and evaluated. Discussion and dissension need to be interdisciplinary. To develop and apply a postmechanistic agricultural ethic, academics involved in agricultural issues—agronomists, animal scientists, ecologists, philosophers, anthropologists, economists, writers, and others—must become engaged in the dialogue about appropriate agricultural technique. The historical separation among the disciplines is an impediment to postmechanistic agricultural ethics.

Moreover, the discussion ought to take place free from corporate constraints. Land grant universities need to vigorously pursue research, teaching, and praxis that is based on ecology, not solely on economics. No longer can we expect to blithely conduct research or promote a new technology that does not clearly advance a context-sensitive postmechanistic agricultural ethics. Although many scientists involved in some aspect of agricultural research (and particularly those in very basic plant molecular genetics) feel their work will lead to improved environmental health (Briggs 1998), rigorous evaluation of their research and claims in terms of ecological integrity is lacking. Far more consideration should be given to the effect that particular genes, genotypes, crops, or cropping systems may have on altering the agroecosystem and agricultural landscape. A recent report suggests that widespread adoption of herbicide-resistant crops could have negative implications for seed-eating birds (Watkinson et al. 2000), a finding that clearly underscores why the relationship between reductive genetic manipulation and ecosystem functioning needs to be considered.

In short, land grant institutions, rather than being appendages of corporate interests, should be havens for discussion and dissension free from market forces. The German philosopher Friedrich Nietzsche's ([1885] 1995) admonition is strangely appropriate: "Far from the market place and from fame happens all that is great: far from the market place and from fame the inventors of new values have always dwelt." The agricultural industry is not excluded from this discussion, but in order to make a significant contribution to the sustainable agriculture of the future, it will need to place the good of the agroecosystem above the full economic exploitation it currently pursues.

A specter hangs over future improvements in agricultural sustainability. Current governmental farm policies often discourage the development of a context-sensitive agriculture by subsidizing a few commodity crops, such as maize and soybeans in the United States. Government policies need to be structured so that they advance, rather than subvert, ecological integrity. Instead of providing funds to

maintain a commodity-based agricultural system, governmental investments should focus on the development of agricultural systems that will revitalize and stabilize agroecosystems (Stauber 1997)—in other words, farmers should be supported to farm small areas well, rather than to farm large areas poorly.

Conclusion

Notwithstanding the supersession of deterministic Newtonian mechanics by indeterministic quantum mechanics in physics, the mechanistic view of nature has maintained its hegemony on Western thinking in general and is clearly manifested in current industrial agricultural practice. Contrary to modern industrial technique, postmechanistic technique sees farming as a multifaceted activity that, in addition to mechanistic investigation and practice, involves the recognition of a variety of noneconomic values in the land: ecological, aesthetic, historical, political, social, even spiritual. Our concept of agriculture is that it is more than simply food production: It is the act of affirming as many of these values as possible (Figure 4).



Figure 4. This aesthetically pleasing mixture of row crops (maize and soybean) with hay and pasture and grazing cattle on an entirely organic farm in Harlan County, Iowa, represents one step toward affirming a postmechanistic agricultural ethic.

We call on land grant institutions, federal and state agricultural agencies, and the food-consuming public to recognize the plenitude of values involved in the activity of farming. A postmechanistic agricultural ethic encourages the farmer to facilitate the emergence of the special properties of his or her unique place, rather than to repress the intrinsic beauty and value of the land through simplification and homogenization. A reworking of Earl Butz's injunction is appropriate for the 21st century: Get sustainable or get out. Farming, after all, is a dynamic and complex enterprise; we should be loath to diminish, in any way, its wonder and surprise.

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References cited

- Agricola G. [1556] 1912. *De re metallica*. Hoover HC, Hoover LH, trans. Mining Magazine (London), p. 337.
- Arabidopsis Genome Initiative. 2000. Analysis of the genome sequence of the flowering plant *Arabidopsis thaliana*. *Nature* 408: 796–815.
- Balvanera P, Daily GC, Ehrlich PR, Ricketts TH, Bailey S-A, Kark S, Kremen C, Pereira H. 2001. Conserving biodiversity and ecosystem services. *Science* 291: 2047.
- Berry W. 2000. *Life Is a Miracle*. Washington (DC): Counterpoint Press.
- Briggs SP. 1998. Plant genomics: More than food for thought. *Proceedings of the National Academy of Sciences* 95: 1986–1988.
- Brummer EC. 1998. Diversity, stability, and sustainable American agriculture. *Agronomy Journal* 90: 1–2.
- Carson R. [1962] 1994. *Silent Spring*. Boston: Houghton Mifflin.
- Chory J, et al. 2000. Functional genomics and the virtual plant: A blueprint for understanding how plants are built and how to improve them. *Plant Physiology* 123: 423–425.
- Costanza R, et al. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253–260.
- Descartes R. [1641] 1989. *Meditations on first philosophy*. Page 84 in Cottingham J, Stoothoff R, Murdoch D, trans. and eds. *Descartes: Selected Philosophical Writings*. New York: Cambridge University Press.
- Drinkwater LE, Wagoner P, Sarrantonio M. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396: 262–265.
- Ferré F. 1996. *Being and Value: Toward a Constructive Metaphysics*. Albany (NY): State University of New York Press.
- Golley FB. 1998. *A Primer for Environmental Literacy*. New Haven (CT): Yale University Press.
- Hobbes T. [1651] 1985. *Leviathan*. MacPherson CB, ed. New York: Penguin Books.
- Hulot FD, Lacroix G, Lescher-Moutoué F, Loreau M. 2000. Functional diversity governs ecosystem response to nutrient enrichment. *Nature* 405: 340–344.
- Hume D. [1740] 1992. *A Treatise on Human Nature*. New York: Oxford University Press.
- Jackson W. 1987. *Altars of Unhewn Stone: Science and the Earth*. San Francisco: North Point Press.
- Keller DR. 1997. Gleaning lessons from deep ecology. *Ethics and the Environment* 2: 139–148.
- Keller DR, Golley FB. 2000. *The Philosophy of Ecology: From Science to Synthesis*. Athens: University of Georgia Press.
- Kunetka JW. 1982. *Oppenheimer: The Years of Risk*. Englewood Cliffs (NJ): Prentice-Hall.
- Latham JR. 2000. There's enough food for everyone, but the poor can't afford to buy it. *Nature* 404: 222.
- Leopold A. [1949] 1987. *A Sand County Almanac and Sketches Here and There*. New York: Oxford University Press.
- Lewis WJ, van Lenteren JC, Phatak SC, Tumilson JH III. 1997. A total system approach to sustainable pest management. *Proceedings of the National Academy of Sciences* 94: 12243–12248.
- Lewontin R. 2000. *The Triple Helix: Gene, Organism, and Environment*. Cambridge (MA): Harvard University Press.
- Locke J. [1690] 1985. *An essay concerning human understanding*. Page 491 in Cahn S, ed. *Classics of Western Philosophy*, 2nd ed. Indianapolis (IN): Hackett Publishing.
- . [1689] 1996. *Second treatise of government*. In Morgan M, ed. *Classics of Moral and Political Theory*. 2nd ed. Indianapolis (IN): Hackett Publishing.
- Matson PA, Parton WJ, Power AG, Swift MJ. 1997. Agricultural intensification and ecosystem properties. *Science* 277: 504–509.
- Merchant C. 1990. *The Death of Nature: Women, Ecology and the Scientific Revolution*. San Francisco: Harper Collins.
- Nietzsche F. [1885] 1995. *Thus Spoke Zarathustra*. New York: Random House.
- Odum EP. 1986. Introductory review: Perspectives of ecosystem theory and application. Pages 1–11 in Polunin N, ed. *Ecosystem Theory and Application*. New York: John Wiley and Sons.
- Oelschlaeger M. 1991. *The Idea of Wilderness: From Prehistory to the Age of Ecology*. New Haven (CT): Yale University Press.
- Ovid. 1993. *Metamorphoses*. Mandelbaum A, trans. New York: Harcourt.
- Rosen R. 1991. *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. New York: Columbia University Press.
- Russell B. 1961. *Religion and Science*. New York: Oxford University Press.
- Samuelson P. 1980. *Economics*. 11th ed. New York: McGraw-Hill.
- Serageldin I. 1999. Biotechnology and food security in the 21st century. *Science* 285: 387–389.
- Sinclair TR, Cassman KG. 1999. Green revolution still too green. *Nature* 398: 556.
- Somerville C, Somerville S. 1999. Plant functional genomics. *Science* 285: 380–383.
- Staub K. 1997. Envisioning a thriving rural America through agriculture. Pages 105–117 in Lockeretz W, ed. *Visions of American Agriculture*. Ames: Iowa State University.
- Stevens WK. 1997. How much is nature worth? For you, \$33 trillion. *New York Times*, 20 May, sec. C.
- Thies C, Tscharnkte T. 1999. Landscape structure and biological control in agroecosystems. *Science* 285: 893–895.
- Thompson PB. 1995. *The Spirit of the Soil*. New York: Routledge and Kegan Paul.
- Tilman D. 1999. Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. *Proceedings of the National Academy of Sciences* 96: 5995–6000.
- Tilman D, Reich PB, Knops J, Wedin D, Mielke T, Lehman C. 2001. Diversity and productivity in a long-term grassland experiment. *Science* 294: 843–845.
- Vitousek PM, Mooney HA, Lubchenco J, Melillo JM. 1997. Human domination of Earth's ecosystems. *Science* 277: 494–499.
- Watkinson AR, Freckleton RP, Robinson RA, Sutherland WJ. 2000. Predictions of biodiversity response to genetically modified herbicide-tolerant crops. *Science* 289: 1554–1557.
- White L. 1967. The Historical Roots of Our Ecologic Crisis. *Science* 155: 1203–1207.
- Whitehead AN. [1925] 1967. *Science and the Modern World*. New York: Free Press.
- . [1929] 1978. *Process and Reality: An Essay in Cosmology*. New York: Free Press.
- Williams RJ, Martinez ND. 2000. Simple rules yield complex food webs. *Nature* 404: 180–183.
- Zhu Y, et al. 2000. Genetic diversity and disease control in rice. *Nature* 406: 718–722.