It Starts with the Soil and Organic Agriculture can Help[1]

Frederick Kirschenmann

> *We must look at our present civilization as a whole and realize once and for all the great principle that the activities of homo sapiens, which have created the machine age in which we are now living, are based on a very insecure basis---the surplus food made available by the plunder of the stores of soil fertility which are not ours but the property of generations yet to come.*
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> ---Sir Albert Howard, *The Soil and Health* (1947)

The foundation of modern science has deep roots in Western culture, reaching back to the 16th and 17th centuries. The central dogma underlying this science is rooted in the mathematics-based science of Rene Descartes. In his *Meditations* published in 1641, Descartes asserted that one could and must separate the thinking mind (or subject) from the material world (or object). By doing so, he believed one could establish objective certainty, wholly determinable, and free of any subjective bias. It was on this basis that Descartes reduced material reality to mechanical functions. This perspective formed the basis of the “disinterested” sciences and eventually yielded the knowledge, technologies and culture that made industrial science and ultimately industrial agriculture possible. This philosophy of science also shaped our perceptions of soil within modern agriculture.

Descartes’ view of the world as a collection of mechanistic fragments was part of an emerging school of thought. Francis Bacon, a contemporary who espoused this same philosophy, promoted the idea that nature must be controlled and manipulated for the exclusive benefit of humans. We need to “bend nature to our will” as he put it. Descartes was similarly convinced that with this new science we would become the “masters and possessors of nature.”

Together Descartes and Bacon led the way in developing a culture that viewed nature, including soil, as a collection of mechanistic fragments to be manipulated for our own benefit. Perceiving nature as a collection of objects separate from us and promoting the belief that nature could be controlled and dominated for our benefit perhaps made it inevitable that most modern soil scientists would view soil as a thing to be manipulated rather than a web of relationships to be appreciated. Sir Albert Howard, Aldo Leopold, Hans Jenny and a few others were the exception to the rule.

Influenced by Cartesian science, Justus von Liebig published his *Chemistry in the Application to Agriculture and Physiology* in 1840. Von Liebig argued that we could simplify agricultural production and increase crop yields without the laborious task of enhancing humus in the soil. All one needed to do was insert chemical fertilizers into the soil. In 1843 John Bennett Lawes

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and J. H. Gilbert manufactured and patented superphosphates, built the first fertilizer factory and proceeded to demonstrate the validity of Liebig’s thesis. Eventually the ability to substitute chemical fertilizers for nutrient cycling practices encouraged farmers to specialize, focus on a few high-value crops grown in monocultures, and abandon integrated crop/livestock systems which incorporated livestock manure and green manure into the soil.

Sir Albert Howard and a few other agriculturalists at the time took strong exception to this approach to soil management. Howard complained that given Liebig’s “NPK mentality,”

> . . . the soil in general and the humus in it were looked on as mere collections of material without organic growth of their own; there was no conception of their living nature and no knowledge whatever of fungous or bacterial organisms, of which humus is the habitat. Liebig had no difficulty in disproving the role of humus when presented in this faulty way as dead matter almost insoluble in water. He substituted for it a correct appreciation of the chemical and mineral contents of the soil and of the part these constituents play in plant nourishment.
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> This was a great advance, but it was not noticed at the time that only a fraction of the facts had been dealt with. To a certain extent this narrowness was corrected when Darwin in 1882 published *The Formation of Vegetable Mould Through the Action of Worms, with Observations of Their Habitat*, a book founded on prolonged and acute observation of natural life. The effect of this study was to draw attention to the extraordinary cumulative result of a physical turnover of soil particles by natural agents, particularly earthworms. It was a salutary return to the observation of the life of the soil and has the supreme merit of grasping the gearing together of the soil itself and of the creatures who inhabit it. (Howard 2006)

Other agriculturalists of his day shared Howard’s dismay at this “machine age” approach to managing the soil. But the powerful allure of the simple, effective, almost magical manner in which productivity could be increased proved too seductive for most agriculturalists to ignore. As Aldo Leopold observed in 1945, “It was inevitable and no doubt desirable that the tremendous momentum of industrialization should have spread to farm life.”

However, like Howard, Leopold (1999) also recognized the vulnerabilities of this industrial approach;

> It is clear to me, however, that it has overshot the mark, in the sense that it is generating new insecurities, economic and ecological, in place of those it was meant to abolish. In its extreme form, it is humanly desolate and economically unstable. These extremes will some day die of their own too-much, not because they are bad for wildlife, but because they are bad for the farmers.

The Role of Soil in the Future of Agriculture

While organic farmers, and soil scientists in the organic movement have long recognized the fallacies inherent in this industrial approach to soil management, their exhortations for a more ecological approach to soil management have largely been ignored. However, as we enter the 21st century the insecurities perceived by Leopold are beginning to manifest themselves and there are urgent reasons to reevaluate the way we have come to think about soil. There are at least three natural resources essential to the successful management of Liebig's method and each of them now face steep declines.

The first of these essential resources is *energy.* Liebig's input/output system, the foundation of our modern industrial agriculture, depends almost entirely on fossil fuels. The nitrogen used for fertilizer is derived from natural gas. Phosphorus and potash are mined, processed and transported to farms with petroleum energy. Pesticides are manufactured from petroleum resources. Farm equipment is manufactured and operated using petroleum-based energy. Irrigation is accomplished with petroleum energy.

As long as fossil fuels were abundantly available they provided a cheap source of energy for Liebig's energy-intensive input/output soil management system making it difficult for Howard's self-renewing, recycling system to compete. Most independent scholars agree, however, that we now have either reached peak oil production or will do so shortly. (Heinberg 2004, Roberts 2004) The era of cheap energy is over and, more than any other natural resource, the lack of cheap energy may force us to rethink the way we manage soil. Restoring the soil's ecological health may become a logical imperative in the 21st century.

Of course alternatives to fossil fuel energy are available---wind, solar, biofuels, etc. Theoretically one can contemplate replacing oil and natural gas with alternative sources of energy to keep industrial agriculture viable. But the reality that we must face is that our industrial economy was created on a platform of *stored, concentrated energy* which produced a very favorable energy *profit ratio*---the energy return for energy invested.. Alternative energy sources are based on *current, dispersed* energy which has a far lower energy profit ratio.

The primary sources of stored, concentrated energy are coal, oil and natural gas. So far as anyone knows there are no other sources of stored, concentrated energy available on the planet. Consequently, economies based on industrial production systems fueled by cheap energy are not likely to fare well in the future. Consequently the depletion of our fossil fuel resources will not only require that we transition to *alternative* fuels to produce our food, but also that we adopt a new energy *system*.

The energy transition that we must contemplate involves converting from an energy *input* system to an energy *exchange* system. An energy exchange system requires biological diversity, organized so that each organism exchanges energy with other organisms in the land community, forming a web of synchronous relationships, instead of relying on energy-intensive inputs. Such alternative systems were implicit in Howard's principles of soil management as well as those of other organic visionaries of the early 20th century.

A relatively *stable climate* is the second natural resource that has been essential to the highly specialized production system that evolved from Liebig's input/output soil management paradigm. We often mistakenly attribute the yield-producing success of Liebig's soil management system entirely to the development of the new production technologies. However that robust production was at least as much due to the unusually favorable climate conditions of the past century as it was to the Green Revolution technologies. Such advantageous climates are atypical.

A National Academy of Sciences (NAS) Panel on Climactic Variation reported in 1975 that "our present [stable] climate is in fact highly *abnormal*," and that "the earth's climates have always been changing, and the magnitude of . . . the changes can be catastrophic." The report concluded that "the global patterns of food production and population that have evolved are *implicitly dependent* on the climate of the present century." It further suggested that climate change might be further exacerbated by "our own activities." (NAS 1975) According to NAS, it is this *combination* of "normal" climate variation *plus* the changes stemming from our own industrial economies (greenhouse gas emissions) that could have a significant impact on our future agricultural productivity.

Given our current soil management paradigm, the impact of such climate change on production agriculture could be especially severe. While it is impossible to predict exactly how climate change will affect agricultural production in the near term (Rosenzweig and Hillel 1995), most climatologists agree that we can anticipate greater climate fluctuations---"extremes of precipitation, both droughts and floods." (Rosenzweig et al. 2001) Such instability can be especially devastating for the highly specialized, genetically uniform, monoculture systems so characteristic of the industrial agriculture that dominates the landscape today.

Once again insights from organic visionaries like Howard can lead us in a direction that can help us cope with some of the effects that climate change may have on agriculture. Contrary to the specialization, simplification and concentration typical of industrial economies, Howard envisioned a farming system based on the economy of nature.

> Mother earth never attempts to farm without livestock; she always raises mixed crops; great pains are taken to preserve the soil and to prevent erosion; the mixed vegetable and animal wastes are converted into humus; there is no waste; the processes of growth and the processes of decay balance one another; ample provision is made to store the rainfall; both plants and animals are left to protect themselves against disease. (Howard A, 1943)

A third natural resource that may challenge our current soil management system is *water*. Lester Brown points out that while we each need only four liters of water to meet our daily liquid requirements, our current industrial agriculture system consumes 2,000 liters of water per day to produce each of our daily food requirements. A significant amount of that water is used by production agriculture under our current soil management system. Agricultural irrigation alone consumes more than 70 percent of our global fresh water resources. (Brown 2006) We use twice the amount of water for agricultural irrigation today as we did in the 1960s. Consequently we are drawing down our fresh water resources at an unsustainable rate.

Water tables in the Ogallala Aquifer, which supplies most of the water for irrigation in the great plains of the United States, are being overdrawn at the rate of 3.1 trillion gallons per year (BBC 2000) and according to some reports this fossil water bank is now half depleted. (Soule and Piper 1992)

Reduced snow packs in mountainous regions due to climate change will decrease spring run off (a primary source of irrigation water in many parts of the world), further stressing our water shortages. This is just one critical example of the interdependence of our natural resources and likely will force us to reconsider how we manage our soils. Again, the principles of soil management embedded in the writings of Howard and others in the organic movement can help us redesign farming systems that function within the ecological constraints imposed by nature.

Back to the Future

We know both from research and on-farm experience that when soils are managed in accord with the “law of return,” the soil’s capacity to absorb and retain moisture is significantly enhanced, reducing the need for irrigation. We also know from on-farm experience (as well as from nature’s own elasticity) that diverse systems are more resilient than monocultures and therefore perform better under adverse climate conditions. On-farm experience also tells us that energy inputs can be dramatically reduced when input/output systems are replaced by recycling systems.

All of these factors give renewed credence to Howard’s soil management vision. We should seek new ways to adopt his principles on the landscape as we face our challenging, post-industrial future.

Exploring new insights developed by modern ecology and evolutionary biology, and applying them to modern nutrient recycling and humus-based farming, could provide us with additional critically needed intellectual capital. Such knowledge could assist us in developing concrete models of humus-building soil management and ecologically-based farming systems appropriate to farms within specific ecosystems.

Soil is, of course, a very dynamic, emergent property with its own local characteristics and has been both accumulating and eroding for millennia. (Charman and Murray eds 2000) Soil erosion due to human activity has, for centuries, been a major contributing factor to humankind’s failure to sustain civilized societies (Lowdermilk 1953) and there is no good reason to believe that our current civilization is exempt from a similar fate.

Yet, while soil loss due to wind and water erosion contributes significantly to diminished soil quality, a more troubling aspect of soil loss as we enter a world devoid of cheap energy, surplus water and stable climates, is the drawdown of much of the remaining soil’s “stored fertility,” as Howard (2006) described humus-rich soil.

As we navigate our way toward a program of soil management that addresses our future challenges it becomes especially important to remember that soil is “not a thing” but “a web of relationships" always unique to its time and place. (Logan 1995) Soil, as Hans Jenny noted, is "part of a much larger system that is composed of the upper part of the lithosphere, the lower part of the atmosphere, and a considerable part of the biosphere." The living organisms in the soil then become part of soil formation in relationship to all the other factors---climate, topography, parent material, time, nitrogen content, etc. Life in the soil adapts to its place much as do other life forms---microbes, vegetation, animal life, humans. (Jenny 1941) Soil is a dynamic, emergent property that can be managed to dramatically reduce energy and water consumption, and produce a more resilient, diverse landscape that can more readily sustain productivity in the face of unstable climates.

This, of course, suggests that managing soil properly is as much art as science. The intimate relationship that the farmer has with the soil plays a key role in successful management. We now know from considerable research that soil which is managed as a complex set of relationships, including the use of green manure and livestock manure, can solve many of the production problems which our industrial farming systems now solve with costly inputs that seldom address the root of the problem and require excessive energy inputs. (Mador et al. 2002)

Cheap fossil fuel energy of course enabled us to use artificial inputs to increase food production without attending to intrinsic soil quality. (Russelle et al. 2007) Embracing the "NPK mentality," we ignored the law of return and now we are left with soils essentially depleted of vigor. Recent research has reconfirmed that soil health is not likely to be restored without the return of organic inputs in the form of cover crops, manure and other waste materials. (Teasdale et al. 2007) Consequently, managing soil to restore and enhance its self-renewing and self-regulating capacity will be critical to maintaining productivity in our post-industrial world.

Unfortunately while we have put considerable resources into learning how to manage soil to maximize production in the short term, we have invested very little in learning how to manage soil to achieve ecological health and optimum production in the long term. As Leopold (1949) observed, "The art of land doctoring is being practiced with vigor, but the science of land health is yet to be born."

Establishing a New Land Community on the Farm

So how can we proceed to make this paradigm shift in managing soil? Since farmers have been indoctrinated to believe that yields can be maximized by inserting a few artificial nutrients (the NPK mentality), that no-till (notwithstanding all its benefits) is the silver bullet solution to soil erostion, and that crop residues are "waste materials," it may be challenging to sell them on managing soil as a web of relationships.

While clearly not welcomed by farmers, rising energy costs, restricted water use and more unstable climates, combined with the growing awareness that the industrial system is rife with its own failures, these new conditions could well cause farmers to seek alternatives faster than we can currently imagine.

Researchers have already begun to point out the deficiencies of the industrial farming system. For example, Joe Lewis and his colleagues have clearly articulated the failure of the industrial farming system with respect to pest management. The “single tactic” “therapeutic intervention” strategy (while ignoring the web of relationships in ecosystems management) they point out has clearly failed. They call attention to the opportunities inherent in alternative ecosystem management tactics that in some ways echo Howard’s soil management principles. They point out that while it may “seem that an optimal corrective action for an undesired entity is to apply a direct external counter force against it,” in fact “such interventionist actions never produce sustainable desired effects. Rather, the attempted solution becomes the problem.” The alternative, they propose is “an understanding and shoring up of the full composite of inherent plant defenses, plant mixtures, soil, natural enemies, and other components of the system. These natural ‘built in’ regulators are linked in a web of feedback loops and are renewable and sustainable.” (Lewis at al. 1997)

Approaching pest management or weed control from this ecological perspective inevitably involves a web of relationships that include the way soil is managed. “For example, problems with soil erosion have resulted in major thrusts in use of winter cover corps and conservation tillage. Preliminary studies indicate that cover crops also serve as bridge/refugia to stabilize natural enemy/pest balances and relay these balances into the crop season.” (Lewis at al. 1997) In short, such natural systems management can revitalize soil health, reduce weed and other pest pressures, get farmers off the pesticide treadmill and begin the transition from an energy-intensive industrial farming operation to a self-regulating, self-renewing system.

A more recent example of this new web-of-relationships thinking is evident in Rattan Lal’s warning about using crop residues as a source of renewable energy. He perceives this as

> . . . a dangerous trend because crop residue is not a waste. It is a precious commodity and essential to preserving soil quality. In addition to controlling erosion and conserving soil water in the root zone, retaining crop residues on the soil is also necessary for recycling nutrients, improving activity and species diversity of soil micro- and macro-fauna, maintaining soil structure and tilth, reducing nonpoint source pollution and decreasing the risks of hypoxia in the coastal regions, increasing use efficiency of fertilizers and other inputs, sustaining biomass/agronomic yield, and improving/maintaining soil organic matter content. (Lal 2007)

Other benefits flow from improved soil health, such as greater water conservation. As research conducted by John Reganold (1987) and his colleagues has demonstrated, soil managed in accordance with the “law of return” develops richer topsoil, more than twice the organic matter, added biological activity and far greater moisture absorption and holding capacity.

Such soil management serves as an example of how we can begin to move to an energy system that operates on the basis of energy *exchange* instead of energy *input*. But more innovation is needed. Nature is a highly efficient energy manager. All of its energy comes from sunlight which is processed into carbon through photosynthesis and becomes available to various organisms who exchange energy through a web of relationships. Bison on the prairie obtain their energy from the grass which absorbs energy from the soil. The bison deposit their excrement back onto the grass which provides energy for insects and other organisms which, in turn, convert it to energy that enriches the soil to produce more grass. These sorts of energy exchange systems are exactly what Howard envisioned with his "law of return" concept.

Unfortunately many organic farming systems have subscribed to "input substitution" systems instead of "law of return" energy exchange systems. (Rosset and Altieri, 1997) Input substitution systems still function in accord with industrial principles and require large infusions of energy and water and tend toward large monocultures. While they substitute natural inputs for synthetic inputs, they will likely not fare much better than "conventional" systems in our new energy, water, climate future.

Fortunately a few farmers have developed "law of return" energy exchange systems and appear to be quite successful in managing their operations with very little fossil fuel input. (Kirschenmann 2007) Converting farms to this new energy model involves a major transformation. Highly specialized, energy-intensive monocultures will need to be converted to complex, highly diversified operations that function on energy exchange. The practicality and multiple benefits of such integrated crop-livestock operations have recently been reconfirmed through research (Russelle et al. 2007), but further study will be needed to adapt this new model of farming to various thermo-climes and agro-ecosystems.

By appropriating the values inherent in the writings of organic visionaries like Howard, integrating them with the science of ecology and evolutionary biology developed in recent decades, and field testing these new agroecological systems we may be able to sustain productivity in the face of the production challenges confronting us in the decades ahead.

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