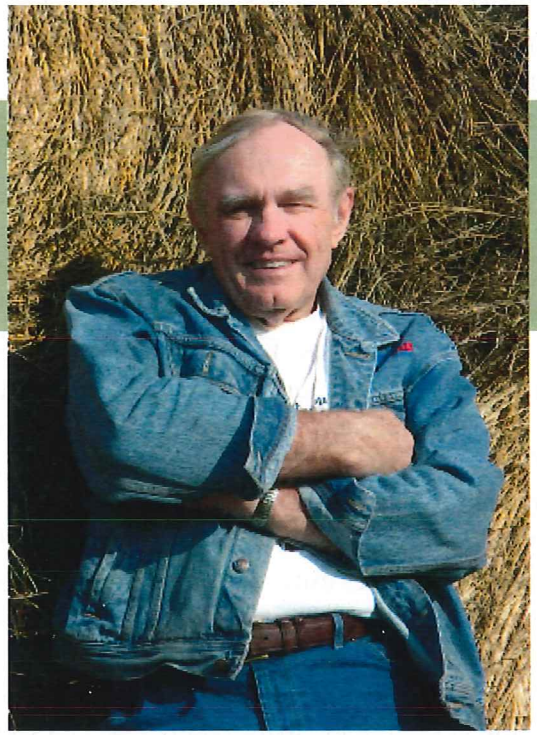

Photo courtesy of Frederick Kirschenmann

Frederick L. Kirschenmann shares an appointment as Distinguished Fellow for the Leopold Center for Sustainable Agriculture at Iowa State University and as President of Stone Barns Center for Food and Agriculture in Pocantico Hills, New York. He served as the Leopold Center's second director from July 2000 to November 2005 and has been recognized widely for his work. He also continues to manage his family's 1,800-acre certified organic farm in south central North Dakota, where he developed a diverse crop rotation that has enabled him to farm productively without synthetic inputs (fertilizers or pesticides) while simultaneously improving the health of the soil. His farm has been featured in numerous publications including National Geographic, Business Week, Audubon, *the* LA Times *and* Gourmet *magazine.*

From Soil to Sustainability*

FREDERICK L. KIRSCHENMANN

...the way was blazed for treating the whole problem of health in soil, plant, animal and man as one great subject, calling for a boldly revised point of view and entirely fresh investigation.

Sir Albert Howard, *The Soil and Health* (1947)

Defining Sustainability

As most everyone interested in sustainability knows by now, the concept has been appropriated by numerous entities and used in various ways, often to achieve different objectives. In his introductory chapter to the excellent 2013 edition of the Worldwatch Institute's *State of the World* report, Robert Engelman coined the term "sustainababble" to reflect this "cacophonous profusion of uses of the word sustainable to mean anything from environmentally better to cool." Increasingly the term is used as a marketing tool, often it is used as an environmental metric, and, of course it is used extensively to describe an "improved" food and agriculture enterprise. While many of these uses may be grounded in good intentions, the result, as Engelman points out, has "a high cost." "Frequent and inappropriate use lulls us into dreamy belief that all of us—and everything we do, everything we buy, everything we use—are now able to go on forever, world without end, amen" (*State of the World*, 2013).

Such a "dreamy belief" has certainly been prevalent in most of the visions of contemporary "sustainable agriculture". Whether one belongs to the school of sustainable agriculture which is fixated on the notion that sustainability can only be achieved by intensifying the technology of our dominant industrial agriculture, or

**References listed in Endnotes*

to the school of "greening" the system by inserting more environmentally friendly practices, or to the school that insists everyone must transition to organic, all are grounded in the belief that the fundamental principles of modern agriculture, which emerged in the early 20th century, can continue. According to this standard we simply need to tinker with the current system, in various ways, to make it "sustainable." While such "tinkering" can sometimes produce positive, short-term, results, it fails to address the new challenges that will emerge in the near future. Occasionally pundits now refer to this "dreamy belief" of sustainability (appropriately, I think) as "band-aid sustainability."

Historical Context

In his engaging book, *Culture and Agriculture: An Ecological Introduction to Traditional and Modern Farming Systems*, anthropologist Ernest Schusky provides us with a summary of how the human species has fed itself since it evolved on planet earth some 200,000 years ago. I think such a historical context can help us to better frame the concept of sustainability. Schusky reminds us that for most of our time on the planet we have fed ourselves as hunter-gatherers. Like many other species, we have tended to live in small bands, gather and hunt the food available in a particular place, until the food sources became depleted—at which point we moved on to another place. Apparently various mechanisms and methods also limited population growth and kept population density within "carrying capacity."

It wasn't until the Neolithic Revolution, approximately 10,000 years ago, that we began to transition from "food collectors" to food producers by domesticating plants and animals. This is when we began to live in settled societies, and to try to produce enough food in place to feed a local, settled population.

As Schusky points out, this new way of feeding ourselves was "land intensive." It tended to mine the natural fertility of the soil. Consequently, much of this early agriculture was based on "swidden cultivation," also known as "slash-and-burn" agriculture. In other words, a common practice was to burn off perennial plants—trees or grasses—and then cultivate the soil and plant seeds (usually cereals). The natural soil fertility, plus the fertility from the ash, produced good yields the first year. After this, however, yields would decline quickly, as natural soil fertility diminished. So the general practice was to slash-and-burn a new plot of ground every year or two, and allow the first to lay fallow for 15 or 20 years, before returning to cultivate it again, after soil fertility was restored.

In the mid-twentieth century we introduced a new form of agriculture—which Schusky calls the "Neocaloric Revolution," since it was largely dependent on external—i.e. artificial, or "new"—inputs. Ironically, almost all of these were, and remain, "old calories"—fossil fuels, fertilizers, fossil water, etc.—which are non-renewable. While the discovery of fossil fuels was the principle innovation which ushered in the industrial revolution, it wasn't until the mid-twentieth century that industrial methods were applied to agriculture on a large scale (Schusky, 1989).

While Justus von Liebig came up with the idea of substituting synthetic fertilizers (Nitrogen, Phosphorus and Potassium) for the "laborious" practices necessary to maintenance of soil health, and Fritz Haber and Carl Bosch devised the means of making ammonia from atmospheric nitrogen in 1909, enabling the conversion to an intensive "input" agriculture, the adoption of these practices did not become dominant in agriculture until after World War II.

There were numerous agricultural visionaries, soil scientists, and ecologists who issued strong warnings that this "N-P-K mentality" (as Sir Albert Howard called it) was the wrong direction for agriculture to take, since it was contrary to the workings of nature and was, in fact, a "form of banditry" since it would steal the availability of healthy soil from future generations (Howard, 1943). F. H. King, Liberty Hyde Baily, Aldo Leopold, William Albrecht, Hans Jenny, Wes Jackson, and many others voiced similar concerns. They saw that maintaining the health of soil was crucial to any kind of truly sustainable agriculture, and were all aware that the modern industrial agriculture was still extremely "land intensive" and therefore damaging to the health of the land. We simply replaced healthy soil with "old calorie" inputs.

Of course, the immediate short-term benefit of

Photograph: Justin Hayworth

industrial agriculture—maximum, efficient production for short-term economic return—was too compelling to permit serious discussion of these visionaries' warnings.

Schusky reminds us that our "neocaloric era" will of necessity be a very short period in the time-line of human history. We seldom consider that "modern" agriculture is dependent on a collection of "old" (non-renewable) calories which we are rapidly depleting. We also seem to forget that the first producing oil well in the US became operational in Titusville, Pennsylvania, in 1859, and it has been fossil fuels (especially petroleum) that provide the cheap energy necessary to sustain the entire "neocaloric" economy. But all of these old calories are *stored, concentrated energy*—fossil fuels, rock phosphate, potash, fossil water, etc.—and these old calories accumulated in the planet over many millennia. Once they are gone, the neocaloric era, according to Schusky, must end, and we will need to redesign a new agriculture that can be "sustainable" in the post-neocaloric era.

The point to remember in all this is that—unless someone finally finds a way to invent a perpetual motion machine—current, diffuse energy (sunlight) will never be as efficient (in terms of energy-return for energy investment) as stored concentrated energy. Consequently, any alternative energy we may invent in the future will never be as "cheap" as fossil fuels have been.

In addition, we need to acknowledge the ecological damage that the excessive use of the old calories has caused—damage that will further affect the "sustainability" of agriculture—more severe weather events due to climate change, eroded and degraded soils, depleted biodiversity and degrading fresh water resources. These are the "sustainability" challenges that will confront us in the decades ahead.

Of course, as the old calories get used up, they will become increasingly expensive, bringing the neocaloric era to an end due to prohibitive costs long before all the calories are gone.

With this preface in place, it is now possible to frame the question of our future food and agriculture system's sustainability by asking ourselves whether we will still be able to "sustain" the current, industrial system (along with any "Band-Aids" we might apply) when crude oil is $350 a barrel, fertilizer costs are five times what they are today, we only have half the amount of fresh water currently available, we have twice the number of severe weather events, and our soils are even

more degraded than they are today.

Anticipating the Future

Given the changes coming at us, it will be difficult to sustain a future food system unless we anticipate the changes and get a head start preparing for them. Perhaps we can learn a critical lesson from the research conducted by Jared Diamond for *Guns, Germs and Steel.* Based on his intensive studies of past civilizations, he has concluded that those civilizations that anticipated the changes coming at them, recognized the value of their ecological reserves, and got a head start preparing for the changes, were the civilizations that tended to survive for the long term. They were "sustainable," while those that failed to do those things were the ones that tended to collapse (Diamond, 2005). If we keep this in mind, it renders another of Schusky's observations concerning human culture more important and more sobering. Schusky observes that "humans manipulate their cultures to achieve many practical, short-range goals; what they do not foresee are many more long-term undesirable consequences. Innovations that solve immediate problems often have built-in effects that eventually will cause major problems" (Schusky, 1989). I would submit that it is important for anyone interested in achieving agricultural "sustainability" to consider Diamond's and Schusky's observations side-by-side.

Taking this as a given, it seems to me that the most urgent priority before us now is to do all we can to restore the biological health of our soils, before the remaining old calories become too expensive to be a viable resource for continuing to "sustain" our food system. Of course other issues will need to be addressed at the same time—crucial among them—putting a cap on carbon, restoring our biological and genetic diversity as much as possible, restoring as many perennials as possible (forests and grasslands), eliminating food waste, implementing the "right to food" and other recent UN proposals (UN reports, 2008–2013). However, the key to future food sustainability will be biologically healthy soil!

Beacons to Guide Us

Fortunately, we are not without practical wisdom to guide us as we design a new agriculture for the post-neocaloric era.

There are a few beacons of light to guide us. I prefer to call them "beacons," rather than "models," since we tend to think of models as examples that can be duplicated. In our new world, we will need to pay much more attention to the uniqueness of each ecological "neighborhood," and to design agricultural systems that are suited to each ecology, rather than imagining another uniform, homogenized, global agriculture typical of the agriculture which has evolved in the "neocaloric era."

Here are a few of the "beacons" that can show us the way on our journey to future sustainability:

Deborah Koons Garcia, "The Symphony of Soil"

This new documentary on soil is a masterpiece of science and art which can be used to transform the way our culture thinks about soil. No one can watch this video and still think that soil is just "dirt." It not only describes how soil was formed over many millennia, but also how to care for it and restore its biological health. The documentary can be obtained from Lily Films Inc.

NRCS and Cover Crops

In recent months the Natural Resources Conservation Service, under the leadership of Ray Archuleta, has become very active, working with farmers and soil scientists to incorporate cover crops—a crop grown for the protection and enrichment of the soil—into monoculture farming operations, with significant results toward beginning a process of restoring soil health. Farmers who have incorporated these practices for a period of five to seven years have discovered that the improved soil health enables them to reduce their fertilizer and pesticide inputs by 70 percent and still maintain yields. Furthermore the improved soil health dramatically improves soil moisture absorption capacity, reducing flooding and nutrient pollution, as well as increasing drought tolerance. If you'd like to hear some stories from farmers and soil scientists who've been involved in using cover crops, you can view "Under Cover Farmers," a USDA/NRCS video that's up on Youtube by clicking here.

The American Academy of Microbiology

One of the encouraging recent developments in the area of soil health has been the increasing attention given to the micro-biome in soil. Even soil scientists, as recently as a decade ago, sometimes referred to soil as simply "a material to hold a plant in place." Now we are beginning to understand that soil is a living community of organisms with billions of microbes at its base. While not perfect, a typical article on the subject, "How Microbes Can Help Feed the World," by Ann Reid and Shannon E. Greene, was published in December 2012 by the American Academy of Microbiology. It can be accessed by Googling the Academy.

John Deere, *The Furrow*, "Building Better Soils"

I take further encouragement from the fact that John Deere elected to devote the entire February 2013 issue of its magazine, *The Furrow*, to the subject of soil health. Again, many of the stories in this issue concerned farmers and the benefits they experienced in using soil health-restoring practices. For example, the issue featured Gabe Brown, a "20-year no-till, cover crop, and livestock" farmer near Bismarck, ND, who reported that before he started his soil health farming practices, his fields were only able to "absorb a half-inch of rain-water per hour. Now they'll take in 8 inches." This issue of *The Furrow* can be accessed at JohnDeere.com/Furrow. Brown also has made a video, *Keys to Building A Healthy Soil*, (available on his website at http://brownsranch.us/category/videos/) in which he reports that, while it now costs most conventional monoculture farmers $4.50 per bushel in input costs to raise corn, his costs are $1.41 per bushel.

Matthew Liebman, Ph.D., agronomist at Iowa State University

Dr. Liebman has conducted over ten years of research in which he has compared results from typical two-year monoculture corn/soybean rotations, three-year rotations of corn/beans/small grain with clover, and four-year rotations of corn/beans/small grains/alfalfa and a second year of alfalfa. The two-year rotation relies entirely on synthetic inputs of fertilizers and pesticides and the three- and four-year rotations incorporate modest amounts of livestock manure. His research has demonstrated that the soil health improves in the three- and four-year rotations, while fertilizer and pesticide applications can be decreased by almost 90 percent, all while maintaining yields realizing a return-on-investment in land and labor that is only slightly lower than in the two-year rotation. Liebman's research showed that incorporating perennial prairie strips into conventional corn/soybean monocultures creates comparable ecological benefits. Reports on the published research can be obtained on the Leopold Center web site: www.leopold.iastate.edu.

The Land Institute

In 1976, in Salina, Kansas, Wes Jackson established a research and education institute to explore the possibility of developing perennial grains that could eventually replace annuals. After more than 30 years of research, scientists at the Land Institute have concluded that with additional research it could be possible to replace many annual grains—such as wheat, sorghum, rice and other crops—with perennial varieties. Perennial plants are much more resilient than annuals, and have many soil-building and carbon-sequestration capabilities by virtue of their robust root systems. Scientists have already demonstrated the soil health restoration capacity of such perennial varieties. In the longer-term (post-neocaloric) future, these new varieties are likely to become the core of sustainable grain agriculture. Information can be obtained on the Land Institute web site.

Growing Recognition within the Investment Community of the Importance and Benefits of Restoring Soils' Biological Health

This recognition is not only on the part of farmers and agronomists, but on the part of economists and investors as well. In the April, 2011 issue of his widely read publication, the *GMO Quarterly Letter*, Jeremy Grantham, one of the nation's leading investment counselors, reminded investors that it was "Time to Wake Up: the Days of Abundant Resources and Falling Prices are Over Forever." Grantham pointed out in this essay that investors need to change their investment strategies

if they want to continue to make money on their money. Continuing to invest in cheap raw materials to increase value without paying attention to the natural and social capital which sustain our economies, will not continue to be successful, he said. Among other things, he advises investors to "invest in soil." (A copy of the Newsletter can be obtained by Googling "Jeremy Grantham.")

Woody Tasch, founder of the "Slow Money" investment movement and author of *Slow Money: Inquiries into the Nature of Slow Money: Investing as if Food, Farms and Fertility Mattered*, makes similar points in his book regarding successful investing in the future, and makes even more passionate appeals to "investing in soil health."

Recognition within the Health Care Industries of Soil Health's Importance

Finally, health care professionals are beginning to recognize the relationship between soil health and human health, a connection that Sir Albert Howard had observed back in the 1940s in his book *The Soil and Health* (1947). Howard suggested that we could not have human health without soil health, plant health and animal health—insisting that they are all "one great subject," and that understanding and working with this synergy would become the "health care system of the future."

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The connection between healthy soil, healthy agriculture and healthy humans is now being reiterated by Dr. Daphne Miller, a practicing physician and professor of family medicine at the University of California at San Francisco. In her new book, *Farmacology: What Innovative Family Farming Can Teach Us about Health and Healing* (Miller, 2013), she provides numerous on-the-ground examples of such connections. Ronnie Neff, health care professional at the Johns Hopkins School of Public Health, has also edited a book of essays, some of which suggest the connections between healthy soil and human health (Neff, 2015).

One more work seems worth adding to this list. In their forthcoming book, *The Hidden Half of Nature: The Microbial Roots of Life and Health* (W.W. Norton, 2016), David R. Montgomery and Anne Bikle have made what I think is one of the most important additions to this important topic I have seen. In its essence, the book is a description of the ways in which microbial life in the soil and in us (the "hidden half of nature") is finally becoming evident, and so consequently we are beginning to deeply explore the connections between the microbiome in soil and in our bodies. As we do, the authors tell us, we begin to discover a whole new and critically important dimension of the connections between soil health and human health, and the very important role that the microbial communities play in all this. One paragraph toward the book's end provides a sense of its scope:

> So where does this revolutionary perspective leave us? Put bluntly, many practices at the heart of modern agriculture and medicine—two arenas of applied science critical to human health and well-being—are simply on the wrong path. We need to learn how to work with, rather than against, the microbial communities that underpin the health of plants and people. (p. 255)

Lessons from My Own Farm

My earliest personal lesson about soil health came from my own farm. It began with my father, who started working on our farm with my mother right after they got married in 1930, which was in the midst of the dust bowl. Somehow my father understood that the devastation the dust bowl was wreaking on his land stemmed not just from the weather, but also from the way farmers farmed. Consequently he became determined not ever to let that happen to his farm again, and so "taking care of the land" became his central passion. He began early on to instill that value into his young son.

Later, in my life, when I returned to our farm to manage it and was introduced to organic agriculture, I discovered that managing for soil health was central to the thinking of the early advocates of organic farming;

visionaries like Sir Albert Howard, Lady Eve Belfour, J. I. Rodale, and others. Consequently, I decided to convert our farm to organic practices, and began implementing various strategies for restoring soil health—applying compost, introducing a mixture of crops in a crop rotation pattern—that included alfalfa, a deep-rooted legume that also supplied our ruminant animals with forages for winter feed.

By the 1980s our soil had visibly improved—it was more porous, earthworms and other soil life had dramatically increased. Then, in 1988, we experienced the first dramatic, practical result of this improved soil health. That was the year we experienced the worst drought in the history of south central North Dakota. Our neighbors, who farmed with conventional synthetic inputs, never pulled a combine out of the shed that summer, since all of their crops dried up and died by the time they grew to roughly seven or eight inches tall, due to lack of moisture. Remarkably, by contrast, our fields produced wheat yields that averaged seventeen bushels per acre, despite the severe drought. That result could only be explained due to the increased moisture absorption and storage capacity of our healthier soils.

Coda

One important lesson in all this was articulated clearly by Wendell Berry in an essay that he originally published back in 1980, "Solving for Pattern" (Berry, 1981). In this remarkable essay Wendell pointed out that, in our culture, we tend to try and solve problems in isolation, as if they were detached phenomena that could be solved with single-tactic therapeutic interventions. But in fact problems are always part of a network of interrelated phenomena. Of course, as long as we had all of the cheap "old calories" to perform all of our interventions, we could make the system of therapeutic interventions work relatively well. However, as we enter the post "neocaloric era," at the same time that we have squandered the health of our ecological and social resources (especially the soil), we will need to begin recognizing the ecological complexity of living systems and their self-renewing capacity. If we are to live healthy, productive lives, let alone feed ourselves, in our post-neocaloric future, it will be essential that we sustain our ecological capital (soil being the foundation of that capital). We will need to "solve for pattern."

It is interesting to note that this shift in our thinking is now also being recognized by some of our leading economists. In an essay, published in the January/February, 2011 issue of the *Harvard Business Review*, Michael Porter and Mark Kramer suggested that businesses which wanted to be successful in our future could no longer operate by "the old play-book" of marginalizing labor and raw materials in the interest of maximizing profits, and neither could they continue to externalize social and natural costs in the interest of maximizing short-term profits, since labor, raw materials, social and natural capital (including soil) have now all been so degraded that businesses can no longer be successful unless they "share value" throughout each of these sectors to maintain the health of the whole. As they put it: "Shared value holds the key to unlocking the next wave of business innovation and growth. It will also reconnect company success and community success in ways that have been lost in an age of narrow management approaches, short-term thinking and deepening divides among society's institutions." In other words, we will now need to "solve for pattern."

All of this further suggests, as John Ehrenfeld and Andrew Hoffman propose in their recent book, *Flourishing*, that any of us interested in truly achieving "sustainability" need to move beyond much of the "chatter" about simply buying more "sustainable" products. As they put it " . . . sustainability is not about windmills, hybrid cars, and green cleaners; it is about the way we live. It is about living authentically; it is about our relationship with nature, with each other, and with ourselves. To be sustainable requires a fundamental shift in our way of thinking and goes to the core of who we are as human beings" (Ehrenfeld, 2013).

I would only add that it is also about how we relate to soil!