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Potential for a New Generation of Biodiversity in Agro-ecosystems of the Future

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Abstract
The roots of industrial agricu lture are embedded in the hist oric publication of Justus von Liebig's Chemistry in the Application to Agriculture and Physiology (1840). Von Liebig argued that we could sustain the productivity of agriculture without continuing mixed farming practices and the laborious task of manuring soils. Substituting synthetic fertilizers for such nutrient cycling practices substantially simplified farming practices, and the ability to substitute synthetic fer tilizers for nutrient cycling led farmers to specialize in the production of a few high-value crops and abandon the mixed farming practices which incorporated green manures and livestock into farming systems.

Disciplines
Agriculture | Biodiversity

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As the industrialization of agriculture took hold in the mid-20th century, several assumptions began to be taken for granted. It was assumed that:

- production efficiency could best be achieved through specialization, simplification and concentration;
- therapeutic intervention was the most effective way to control undesirable events;
- technological innovation would always be able to overcome production challenges;
- control management was the most effective way to achieve production results; and
- cheap energy to fuel this energy intensive system would always be available.

Based on these assumptions, our entire agricultural production system was transformed into large-scale, specialized, energy-intensive farming.

As we enter the 21st century most, if not all, of these assumptions are under fire.

The world is experiencing a major energy transformation which is bound to have a profound effect on our industrialized farming systems. At the same time that the global demand for fossil fuels is skyrocketing, the global production capacity of oil and natural gas either has peaked or will shortly do so. Oil and natural gas constitute two-thirds of our hydrocarbon-based economy and provide almost *all* of the energy used on industrial farms. Fertilizers, pesticides, farm equipment, traction fuel and irrigation, which constitute the very core of all industrialized farming systems, are derived almost entirely from fossil fuels.

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[1] Prepared for the 2005 Trisocieties (ASA-CSSA-SSSA) International Annual Meetings Nov. 6-10, 2005 in Salt Lake City, Utah.

Even without any other challenges, this new energy situation may force agriculture, as well as most of the rest of our economy, to change rather drastically and imminently. As Paul Roberts puts it, "the real question, for anyone truly concerned about our future, is not *whether* change is going to come, but whether the shift will be peaceful and orderly or chaotic and violent because we waited too long to begin planning for it."[2]

In addition to the energy transition, there are numerous other challenges that will force agriculture to change. Among them are ecological degradation (much of it caused by industrial agricultural practices), climate change and a severely impaired farm economy.

The degraded condition of the ecosystem services on which agriculture is heavily dependent was described succinctly in the recently issued United Nations "Millennium Ecosystem Assessment Synthesis Report." The report detailed some disturbing conclusions about the state of our global ecological resources.

Produced by 1,360 of our leading scientists from 95 countries, the report's core findings can't help but alarm us. The report found that over the last half century, humans have polluted or over-exploited two-thirds of the earth's ecological systems on which life depends, dramatically increasing the potential for unprecedented and abrupt ecological collapses. And the report determined that most of these ecosystem damages were the direct or indirect result of changes made to meet rising demands for ecosystem services---in particular the growing demands for food, water, timber, fiber and fuel.

In other words, the means by which we have met our basic human needs during the past half century is now the bane of our existence. And the agriculture we have practiced played a key role in that unhappy outcome.

The report goes on to stress that there is no simple fix for this impending disaster. We now have set in motion a series of changes----climate change, biodiversity loss and land degradation---that make it extremely difficult to *restore* ecological health. These changes, together with the loss of both species diversity and genetic diversity, now have severely damaged the *resilience* of ecosystems---the level of disturbance that an ecosystem can undergo without crossing a threshold to a different kind of structure or functioning. So, not only have we degraded the productive capacity of the planet, we also have undermined the planet's capacity for self-renewal and self-regulation.

And if that news were not sobering enough, the report goes on to suggest that additional *new* challenges are on the way. The report anticipates that during the next 50 years demand for food crops will grow by 70 to 85 percent and demand for water by between 30 and 85 percent.[3]

Climate change is likely to be a third driver forcing agriculture to restructure in the decades ahead. Climate change is, of course, partly caused by ecological degradation, as

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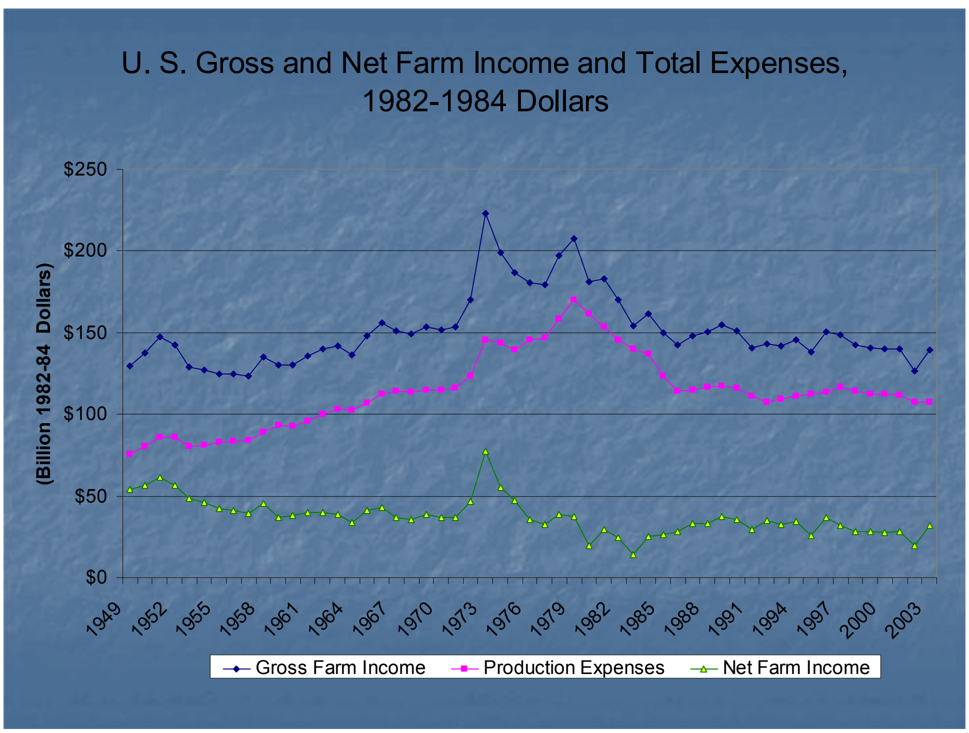
[2] Paul Roberts, 2004. *The End of Oil*. Boston: Houghton Mifflin Company. 14.

[3] United Nations. 2005. "Millennium Ecosystem Assessment Synthesis Report," March. http://www.millenniumassessment.org/en/index.aspx

the UN report suggests. But even apart from human-induced changes, the climate on our planet is seldom stable or consistently favorable to agricultural production. As Stephen Schneider noted several decades ago, while favorable, stable climate plays at least as big a role as technology in producing consistent high crop yields, such favorable climate conditions are not the norm.[4] Industrial agriculture features highly specialized production systems that rely on climate conditions that remain hospitable to those few crops. When 92 percent of Iowa's cultivated land is planted to just two crops---corn and soybeans---climate conditions that are consistently favorable to corn and soybean production will be vitally necessary to maintain productivity. As climate becomes more unstable, such specialized systems will become increasingly vulnerable to climate fluctuations.

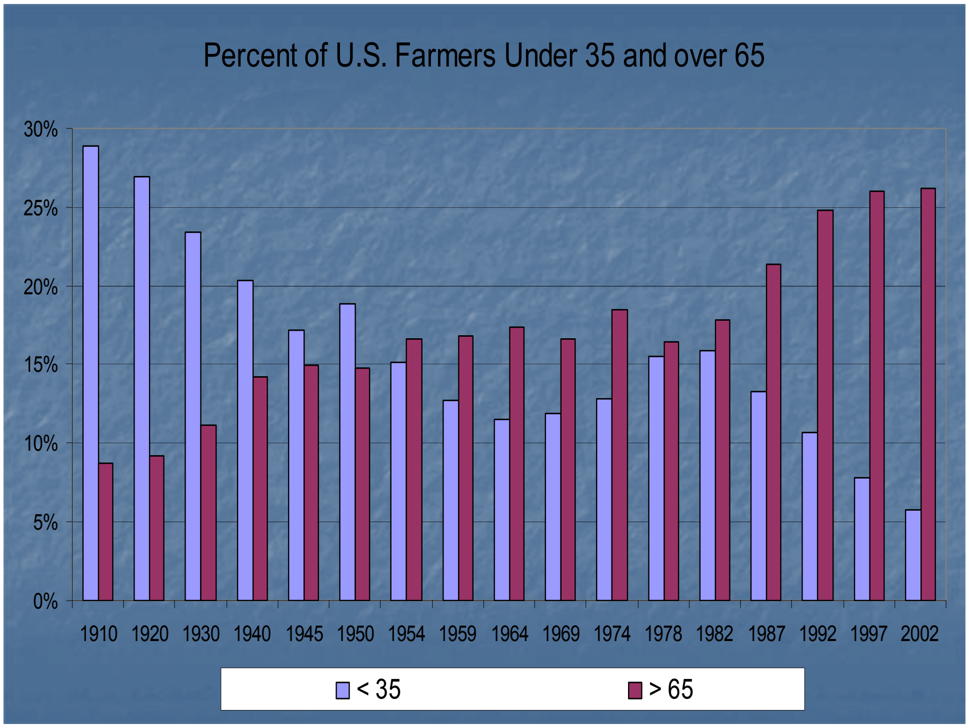
If agriculture is to remain productive, farmers need to be able to adjust quickly to these changing conditions. Since the farm economy has gradually worsened during most of the last half century, farmers may find it very difficult to respond quickly or nimbly. Net farm income has gradually declined since the 1940s, despite an increasing infusion of government subsidies since the mid-1980s. (See Figure 1)



The changing age distribution of farmers may be an additional barrier to change. In 1950, nearly 20 percent of U.S. farmers were under age 35 while less than 15 percent were over age 65. By 2002, only 6 percent were under age 35 while 27 percent were over

[4] Stephen H. Schneider, 1976. *The Genesis Strategy: Climate and Global Survival*. New York: Plenum Press. 103-112.

age 65. (See Figure 2) None of us like to make major changes in our lives once we reach sixty. Farmers may be no exception.



An aging farm population that operates on thinner margins of net income and increasingly rents rather than owns its farmland presents us with a scenario that could inhibit change. Nevertheless, the combination of a volatile energy situation, unstable climate, and degraded ecological resources will prove to be a powerful driver of change. And if we can design farming systems that are less energy intensive, more resilient in the face of unstable climates, and that begin to out-produce monocultures by virtue of their multi-species output, then the economic advantage of such complex farming operations over the dismal financial performance of specialized monocultures could be an additional incentive to change.

A few farmers already operate new, complex farming systems based on biological synergies that are demonstrating incredible efficiencies and economic performance. Takao Furuno's duck/fish/rice/fruit farm in Japan serves as a prime example of such productivity and efficiency. He now produces duck meat, duck eggs, fish meat, fruit and rice in a highly synergistic system of production on the same acreage where he previously only produced rice---all without any exogenous inputs. And, in this new production system, his rice yields have increased up to 50 percent over the yields he was getting from his former high-input, industrial, mono-crop rice farm. His new farm, he writes, is based on the concept of producing "a variety of products within a limited space to achieve maximum overall productivity" by introducing multiple species into the same environment in ways that allow "all components to influence each other positively in a relationship of symbiotic production."[5] Such complex, synergistic systems are proving to be much more productive than mono-cropping systems, while using far fewer, potentially environmentally damaging inputs.

As we enter the 21st century, mainstream agriculture faces many challenges which may propel agriculture in these new directions. As fossil fuels are depleted, the ratio of energy produced to energy required to produce it continues to diminish, making that source of energy increasingly costly. So agriculture will have to find an alternative energy source to sustain its productivity. Agro-ecologists increasingly are convinced that the most viable alternative technology will spring from the biological synergies inherent in multi-species systems and that additional research might make such systems the next new technology.

Masae Shiomi and Hiroshi Koizumi make a strong case for exactly such a transformation in post-modern agriculture. I believe they raise one of the most important questions facing agriculture today: "Is it possible to replace current technologies based on fossil energy with proper interactions operating between crops/livestock and other organisms to enhance agricultural production? If the answer is yes, then modern agriculture, which uses only the simplest biotic responses, can be transformed into an alternative system of agriculture, in which the use of complex biotic interactions becomes the key technology."[6] Farmers like Takao Furuno have already answered that question in the affirmative. Joel Salatin, who operates a similarly complex, synergistic farm in Virginia, concurs.

It would appear that these new farms of the future will operate on the basis of at least eight principles which are almost diametrically opposed to the assumptions industrial agriculture has taken for granted. Post-modern farms will likely need to:

1. be energy conserving,
2. feature both biological and genetic diversity,
3. be largely self-regulating and self-renewing,
4. be knowledge intensive,
5. operate on biological synergies,
6. employ adaptive management,
7. feature ecological restoration rather than choosing between extraction and preservation, and
8. achieve optimum productivity by featuring multi-product, synergistic production on limited acreage and nutrient density.

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[5] Takao Furuno, 2001. *The Power of Duck*. Sisters Creek, Tasmania, Australia: Tagari Publications. 73.
[6] Masae Shiyomi and Hiroshi Koizumi, eds., 2001. *Structure and Function in Agroecosystem Design and Management*. New York: CRC Press. 2, 6.