Module II—
Diminishing the Ecological Footprint

Introductory Remarks

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This module witnesses the competition between two goods, namely agriculture and its related rural environment. They are goods because we all partake of the benefits of agriculture, and we all agree that the condition of and the services (e.g. water cycling, oxygen-carbon dioxide exchange, carbon sinks, pollination, soil formation, nutrient release-capture, and biodiversity) provided by the total environment are vital (Smith, 1974). However, to many environmentalists and conservationists, agricultural development and expansion take place at the expense of the environment; i.e. they are competitors. In that regard they are correct, and the challenge is to balance both interests.

As we view landscapes from airplanes, it is clear that agriculture and forestry are the two human cultures that have most shaped the face of the planet. It could be said that agriculture, with its enormous movements of soil and water, and its international movement of nutrients as foods, is now among the largest geological forces acting on Earth’s surface. It is inevitable that, as the size of the human population increases, the size of the agricultural impacts on the planet will increase, both directly as wild lands are converted to crop production, and as the energy-technology base increases to service the needs of modern agriculture.

Awareness of the impacts of agriculture on the environment is not new. Bismarck observed that the trends in agriculture and forestry in Europe during the late 1800s selected for species that flourished under those conditions. He termed them culture lovers (Kulturliebe), as opposed to those species that required more wilderness habitats, which he termed culture haters (Kulturhesse). Indeed, the modern agricultural community has brought about major changes in the community structure of animal populations. This is apparent in the species composition of waterfowl populations of Europe and North America that benefit from the vast areas of cereal grain culture.
Prairie grouse species eclipsed by the advent of agriculture were replaced by introduced game-birds, such as Asiatic pheasants and European partridges. During the last 30 years, the rehabilitation of the once-endangered wild turkey (*Meleagris gallopavo*) has succeeded because it has adjusted to cash-crop/hardwood landscapes throughout its ancestral range. White tailed deer (*Oidocoleus virginianus*) populations have undergone enormous increases throughout North America due to the effects of grain agriculture and the abandonment of agricultural lands to early ecological succession. These are just a few of the examples that can be mentioned.

Generally, most of society sees this as being good, as an ability of nature to profit from agricultural imposition upon the landscape. Modern programs of wildlife management, itself an offshoot of applied production agriculture, exploit the agricultural environment and its new suite of species, to provide recreation for the public. Few are aware of the decline of many native species and their replacement by desirable species, and even fewer see that as environmentally problematic.

During the early 1900s, the ecologist Aldo Leopold documented in detail the very competitive effects of over-grazing on native plant communities by sheep, goats and cattle, the wide-scale erosion of the southwest of the United States, and the introduction of exotic forage species. His writings explained the ephemeral nature of open-range ranching in this part of the continent (Leopold, 1933; Callicott, 1991). What appears natural and acceptable to us depends very much on our personal timeframe: in essence, it is what we can remember and relate to. After some time, exotics and farmed landscapes (just like human immigrants) acquire a sort of ecological citizenship (such as the mustang, the burro, the feral pig, wheat, sheep and cattle). The same can be said of modern forested landscapes, complete with their many exotics, reduced diversity, monocultures, and longer cycles of cash-crop production.

We accept the radically modified landscapes of agricultural Europe and North America, despite their changed biological diversity and community structure. Large, lush expanses of crops engender a positive feeling, no matter how simple the plant community structure. The Caledonian Forest that once covered so much of Britain has, over two millennia, been replaced by a system of small land parcels interspersed by hedges and small woods, the “idyllic” British countryside. Monocultures of grapevines have long clothed the hillsides of much of France, the Rhine-Moselle regions of Germany, and other parts of Europe, generating a high added-value product. For many parts of Europe and North America, nature is now confined largely to the interstices of the agriculturally modified landscape, and is thus highly susceptible to agricultural change. Society has welcomed these cheap agricultural goods, and provided that there were some adjacent areas of unmanaged lands, no great concerns were raised. However, as human conurbations spread permanently like grease spots, and as agriculture appears to be more consumptive of its land base (as in greater soil erosion, salination, and soil organic matter depletion) and exerts more collateral damage on non-target insect species,
concerns are being expressed. Now, we add the new dimension of biotechnologically changed phenotypes to that mix.

The recent growth of approaches to agriculture termed “lower-input,” “organic,” and “ecological agriculture” reflects an awareness of having to conduct agriculture in a different manner from the current emphasis on the high-energy and high-chemical approach (Thomas and Kevan, 1993). Notwithstanding the savings generated by minimal-till and zero-till cultivation, it is clear that the “greening” of agriculture has a long way to go to reduce its many externalities (Jackson, 2004).

This module’s title, Diminishing the Ecological Footprint, contains two major assumptions that will be addressed. The first is that the agricultural production system is intrinsically sustainable, and that agriculture can be conducted in future with a smaller ecological footprint due to biotechnological advances. The second assumption is that awareness of the value of wild environments to the human well-being will result in societies having a will to achieve a preservation of those wild environments.

This module presents three experts to shed light on those assumptions: William Rees, Klaus Amman and David Lavigne. None is an agronomist, but all are systems ecologists who understand the nature of biological production. This is in keeping with this conference’s desire to solicit insight and debate from outside the discipline of production agriculture.

REFERENCES
Food is the most basic of all resources, and food production has effectively diverted more natural landscape to human purposes than any other ecologically significant human economic activity. Massive famines punctuate the history of human civilization—ironically, since civilization was made possible by agriculture—and, until relatively recently, fear of food shortages was a concern of most human groups.

The reason for fear of famine was most famously explained by the Reverend— and economist—Thomas Malthus in the eighteenth century, in his Essay On the Principle of Population. Malthus observed that “population, when unchecked, increases in a geometric ratio, subsistence increases only in an arithmetic ratio.” A modern Malthus might say that population increases exponentially (like compound interest) while food production increases only linearly (in constant increments). Regardless of how one expresses the relationship, “a slight acquaintance with numbers will show the immensity of the first power in comparison to the second…” In Malthus’s words (1798), “The race of plants and the race of animals shrink under this great restrictive law. And the race of man cannot, by any efforts of reason, escape from it.”

Most people in the developed world today believe that Reverend Malthus was wrong, that industrial “man” has indeed, “by efforts of reason, escaped from it.” Technology-based developments—from the spread of irrigation, extensive use of fertilizers, pesticides and high-yielding crop varieties, to field mechanization and expanding trade—succeeded in keeping global food production ahead of population increases through the last century, with the most spectacular results in the post-WW-II period. Meanwhile, of course, the human population has increased by 152% from 2.5 billion in 1950 to about 6.3 billion today.
But there is reason for pause. By some estimates, after three decades or more of steady increases, world grain production per capita has stabilized or declined since the late 1980s and we have just seen an unprecedented four sequential crop years in which global consumption has exceeded the harvest with each shortfall greater than the one before (Pimentel and Pimentel, 1999; Brown, 2004). According to Brown (2004):

> The grain shortfall of 105 million tons in 2003 is easily the largest on record, amounting to five percent of annual world consumption of 1,930 million tons. The four harvest shortfalls have dropped world carryover stocks of grain to the lowest level in 30 years, amounting to only 59 days of consumption. Wheat and corn prices are at 7-year highs. Rice prices are at 5-year highs.

By some assessments, absolute levels of food production (cereals, pulses, roots and tubers) may have fallen over the past four or five years. Meanwhile, groundwater tables are falling in over half the world’s agricultural areas, soil erosion is rampant, there is increasing evidence that the era of cheap energy—critical to modern agriculture—is ending and population growth continues at 1.3% per year. Are we waking Malthus’s ghost?

In this context, the purpose of this paper is three-fold. First, I examine the prospects for soil/landscape conservation and maintaining adequate global food production through the lenses of ecological-footprint analysis and far-from-equilibrium thermodynamic theory. Can we keep the Malthusian spectre at bay using prevailing approaches to production? Second, I briefly examine the case for genetically modified (GM) crops, the latest “advance” in the so-called high-tech approach to food production. Third, I explain why the prevailing approach to production agriculture, including the introduction of GM crops, has proven so successful in displacing alternatives with arguably more desirable ecological and social characteristics.

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**Ecological footprint analysis** estimates the “load” imposed on the ecosphere by any specified human population or production activity in terms of the land/water area effectively “appropriated” to sustain that population/activity

**The Ecological Footprint of Agriculture**

Ecological footprint analysis (EFA) estimates the “load” imposed on the ecosphere by any specified human population or production activity in terms of the land/water area effectively “appropriated” to sustain that population/activity (Rees,
Agriculture contributes one of the largest components to a typical population eco-footprint.

1992, 1996; Wackernagel and Rees, 1996). Thus, we define the ecological footprint of a study population as (Rees, 2001):

*the area of productive land and water ecosystems required, on a continuous basis, to produce the resources that the population consumes and to assimilate the wastes that the population produces, wherever on Earth the relevant land/water may be located.*

Agriculture contributes one of the largest components to a typical population eco-footprint (EF). This should be no surprise. Brower and Leon (1999) suggested that, next to transportation, food production (meat, poultry, fruits, vegetables and grains) causes the greatest level of environmental impact associated with the average household (Table 1) Transportation and food, together with household operations (heating of space and water, running appliances and lighting) comprise between 64% and 86% of the total ecological impact of household consumption in the several impact categories shown in Table 1.

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<th>Contribution from</th>
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A major component of the food production impact is landscape alteration. For example, about 60% of the US land area is dedicated to crop production or livestock grazing and 45% of the nation’s habitat loss or alteration is due to agriculture. (The US is the world’s greatest agricultural powerhouse.)
Figure 1 shows the per capita cropland eco-footprints (demand) for a selection of countries, and compares these to available domestic cropland per capita (supply). To facilitate comparisons, estimates for each country are presented in terms of world average cropland equivalents using data from the World Wildlife Fund (WWF, 2002). Only land area actually used for growing crops is included in the calculations. Consumption by agriculture to maintain production—energy, fertilizers, pesticides, etc.—is accounted for in other components of the total EF. Nor does this figure include adjustments to reflect unsustainable use of cropland; such adjustments would significantly increase the agricultural eco-footprints of many countries.

![Figure 1](image)

**Figure 1.** Per-capita cropland ecofootprints and domestic cropland for selected countries (1999).

Note that the area of world-average cropland used to produce the diets of today's high-income consumers can be as high as 1.5 hectares (3.7 acres) per capita, typically four to eight times the cropland required by the poorest of the world's poor. Canada's per capita demand for cropland at about 1 hectare is about twelve times that of a typical Bangladeshi or Mozambican.

With prevailing practices, it actually needn't take more than 0.5 hectares (1.2 acres) to provide a diverse high-protein diet like that enjoyed by western Europeans and North Americans (Pimentel and Pimentel, 1999). The fact that there are only 0.25 hectares of cropland available per capita on Earth is a measure of the difficulty in bringing the entire world population up to “northern” dietary stan-
dards. To complicate matters, the domestic cropland available in many poor countries is barely equivalent to national aggregate demand, and in some cases is considerably less (e.g., Peru and Pakistan) (Figure 1). Many densely populated countries have far less than 0.25 hectares of cropland, the area that might be considered their “fair share” of the global total. These countries have no hope of reaching a European-style diet without massive imports of food, a highly unlikely prospect given their chronic poverty and increasing competition on world food markets.

Not only poor countries are net importers of food. Wealthy countries such as Spain, the Netherlands and the United Kingdom have agricultural eco-footprints up to several times larger than their domestic agricultural land bases. Unlike the poorer developing countries, these wealthy nations have, so far, financed their considerable food-based “ecological deficits” with the rest of the world.

Actually, countries that are net food importers are more the rule than the exception. Most of the world’s 183 nations are partially dependent on food imports. Just five countries—the United States, Canada, Australia, France and Argentina—account for 80% of cereal exports and most of the safety net in global food markets (Pimentel and Pimentel, 1999). These countries have exceptionally high cropland-to-population ratios and relatively few soil constraints, and use intensively mechanized, fossil-energy dependent production methods.

It should be clear from even this brief discussion of cropland eco-footprints relative to land supply that land constraints represent a major barrier to increased food production in the future, particularly for those countries that need it the most. Increasing the total area of cropland is possible in some cases, but would require expansion of agriculture into inferior land and massive damage to remaining wildlife natural habitat. Moreover, the following section shows that cropland scarcity is only one of the problems confronting prospects for large-scale increases in food production.

THE BIOPHYSICAL CONTEXT:
FAR-FROM-EQUILIBRIUM THERMODYNAMICS

[Production] agriculture is the use of land to convert oil into food.

—Albert Bartlett

Why is thermodynamic theory relevant to the future of agriculture? Think for a moment of verdant forests, natural grasslands, thriving estuaries, salt marshes, and coral reefs, and of mineral and coal deposits, petroleum, aquifers and arable soils. These are all forms of “natural capital” that represent highly-ordered self-producing ecosystems or rich accumulations of energy/matter with high use potential (low entropy). Now contemplate despoiled landscapes, eroding croplands, depleted fisheries, toxic mine tailings, anthropogenic greenhouse gases, acid rain and anoxic/polluted waters. These all represent disordered systems or degraded forms of energy and matter with little use potential (high entropy). The
main process connecting these two system states is human economic activity, particularly industrial activity, including production agriculture (Rees, 2003). Far-from-equilibrium thermodynamics explains why contemporary growth-bound fossil-energy subsidized development of all kinds must ultimately necessarily destroy the very ecosystems that support it.

The starting point for this interpretation is the second law of thermodynamics. In its simplest form, the second law states that any spontaneous change in an isolated system, one that can exchange neither energy nor matter with its environment, produces an increase in entropy. This means that when a change occurs in an isolated complex system it becomes less structured, more disordered, and there is less potential for further activity. In short, isolated systems always tend toward a state of maximum entropy, a state in which nothing further can happen.

For purposes of this discussion, imagine a homogenized, totally disordered world in which everything is evenly dispersed—there are no distinguishable forms or structures, no gradients of energy or matter. In effect, no finite point in the ecosphere would be distinguishable from any other. We can take this hypothetical randomized distribution of all naturally occurring elements and stable compounds to represent a state of maximum global entropy. It is also, by definition, a state of thermodynamic equilibrium. This is the state toward which the ecosphere would spontaneously gradually descend over time in the absence of sunlight and life. (Entropy can be likened to a relentless form of biophysical gravity.)

Of course, the real world could hardly be more different from this randomized primordial soup. The ecosphere is a highly ordered system of mind-boggling complexity, of many-layered structures and steep gradients represented by accumulated energy and differentiated matter. In the course of several billion years, the trend in the ecosphere has been one of increasing order and complexity, even after allowing for occasional catastrophic setbacks. Millions of emergent organisms have adapted to the many physical environments on Earth, co-evolved in response to each other and their physical environments, and self-organized into differentiated communities and ecosystems. In short, the ecosphere—life—has clearly been moving ever further from thermodynamic equilibrium. So fundamental is this process that, according to Prigogine (1997), “distance from equilibrium becomes an essential parameter in describing nature, much like temperature [is] in [standard] equilibrium thermodynamics.”
How is it that the ecosphere can apparently exist and evolve greater complexity apparently in conflict with the second law? The key is in recognizing that all living systems, from cellular organelles through individual organisms to entire ecosystems are complex, dynamic, open systems that can exchange energy and matter with their host “environments.” As Erwin Schrödinger (1945) observed, organisms are able to maintain themselves and grow “…by eating, drinking, breathing and (in the case of plants) assimilating…” Schrödinger recognized that, like any isolated system, a living organism tends continually to “produce[s] positive entropy—and thus tends to approach the dangerous state of maximum entropy, which is of death. It can only keep aloof from it, i.e. alive, by continually drawing from its environment negative entropy…” (“Negative entropy”—also called “negentropy” or “essergy”—is free energy available for work.) In short, rather than tending toward equilibrium, living systems, from individual foetuses to entire ecosystems, consume “extra-somatic” resources to gain in mass and organizational complexity over time.

In the case of green plants, the extra-somatic energy is actually extra-planetary. Photosynthesis is the chemical process by which plants “fix” as chemical energy a small portion of the incident solar energy reaching Earth. The plants use the resultant products—carbohydrates, fats and proteins—to produce themselves and in the process provide the fuel for most other life-forms, including humans. Indeed, photosynthesis provides the free energy and the organic material building blocks of virtually the entire ecosphere.

Appearances to the contrary, none of this violates the second law. Despite the “negentropy” represented by living, growing systems, production in the ecosphere actually increases the net entropy of the universe as expected. All living systems maintain their local level of organization at the expense of increasing global entropy, particularly the entropy of their immediate host (Schneider and Kay, 1994, 1995). As noted, the ecosphere develops and evolves—maintains itself far-from-equilibrium—by permanently dissipating solar energy. However, since photosynthesis and evapotranspiration degrade a much larger quantity of solar energy than is incorporated in the products, the entropy of the total system increases. Because individual plants, ecosystems and other self-organizing systems develop and grow by continuously degrading and dissipating available energy, they are called “dissipative structures” (Prigogine, 1997).

Like ecosystems, humans and their economies are self-organizing, far-from-equilibrium dissipative structures. However, the human enterprise is but a single sub-system, or “holon,” fully contained within the loose overlapping hierarchy of living, self-organizing, holarchic open (SOHO) systems that comprise the ecosphere (Kay and Regier, 2000). This means that the growth and development of the human enterprise are fuelled all but entirely by the products of photosynthesis, both ancient and contemporary. Human economic activity necessarily feeds on and destroys gradients of usable energy and material first produced by nature. In effect, the human enterprise is thermodynamically positioned to consume the ecosphere from the inside out (Rees, 1999).
Herein lies the proximate cause of the (un)sustainability conundrum in general and the potential crisis in agriculture in particular. Uniquely among sub-systems of the ecosphere (i.e., other consumer organisms), the human enterprise is dominated by positive feedback and auto-catalytic processes. Therefore, it grows continuously, disordering the ecosphere in the process. A critic might argue that every increment of human population growth, each new factory, every addition to the world’s expanding fleet of SUVs, the daily additions to the population of high-tech electronic devices, etc., etc., adds to the scale and complexity of the human enterprise, thus increasing internal order and seemingly moving us ever further from equilibrium. Again, however, beware the illusion—the continuous growth of the human subsystem simultaneously degrades and dissipates the very resources and ecosystems that sustain it. The increasing negentropy of the human sub-system is greatly outweighed by the increased disordering of the ecosphere: global net entropy rises with the erosion of our earthly habitat.

**The two most important gradients feeding the human enterprise are soils and fossil fuels.**

### The Keystone Gradients—Soil and Oil

Arguably, the two most important gradients feeding the human enterprise are soils and fossil fuels. Arable lands and productive soils represent concentrated stocks of the nutrients and organic matter essential for food production. The vital components in soil have accumulated over thousands of years of negentropic interaction among parent soil material, climate and thousands of species of bacteria, fungi, plants and animals, both below and above ground. However, since the dawn of farming 8,000 to 10,000 years ago, agricultural practices have tended to degrade soils and even entire landscapes. This entropic process has tended to accelerate the more allegedly “sophisticated” and productive our agricultural technology becomes. Agriculture-induced erosion, water-logging, acidification, and salination of soils, combined with the dissipation of nutrients (removed with the harvest) and organic matter (the oxidation of agricultural soils is a major source of anthropogenic atmospheric carbon dioxide), have seriously compromised the productivity of large areas of cropland around the world. Since virtually all the readily cultivable land on Earth is already under the plough, more land is coming out of production today because of degradation than is being brought into production.

In recent decades, high-yielding crop varieties, abetted by fossil-energy subsidized irrigation and mechanization and agricultural chemicals (the latter also partly derived from fossil hydrocarbons) have more than compensated for losses of land and natural soil fertility while actually accelerating these losses. Global food production continued to outpace population growth. But, as noted at the outset, ebullience over the so-called “Green Revolution” has been somewhat muted lately.
as the growth of food production stalls and there is increasing evidence that the era of cheap, accessible fossil fuel is coming to an end; accessible reserves are rapidly being dissipated. In this light, consider the following challenges to agriculture in the twenty-first century:

- To keep pace with UN medium population-growth projections, food production will have to increase by 57% by 2050. Improving the diets of billions of people could push the increase toward 100%.
- By 1990, 562 million hectares (38%) of the roughly 1.5 billion hectares in cropland had become eroded or otherwise degraded, some so severely as to be taken out of production. Since then, 5 to 7 million hectares have been lost to production annually (SDIS, 2004). According to the UN Food and Agriculture Organization (FAO, 2000), a cumulative 300 million hectares (21%) of cultivated land—enough to feed almost all of Europe—has been so severely degraded “as to destroy its productive functions.” Only 35% of global arable land is free from degradation.
- Depending on climate and agricultural practice, topsoil is being “dissipated” sixteen to 300 times as fast as it is regenerated.
- Fifty-eight countries, including twenty-one in Europe have no undegraded cropland. More than 60% of the croplands of fifteen European, and twenty-five Asian, African and Latin American nations are severely or very severely degraded (FAO, 2000).
- Since 1967, intensification of agriculture—double-cropping, irrigation, mechanization and chemicals—has accounted for 79 to 96% of the increased yields of wheat, rice and maize (Cassman, 1999). Fossil energy is a major factor, both as a feedstock in fertilizer and pesticide production and as a direct energy source. Primary level (farm level) agriculture in Canada, for example, now represents 5% of the national energy budget and energy accounts for 20% of annual farm expenses (CAEEDAC, 1998).
- While sparing natural ecosystems from conversion to agriculture, this intensification of crop production has accelerated the degradation/dissipation of natural soils, disrupted nutrient cycles, lowered groundwater tables, and contributed to ground and surface water pollution (Cassman, 1999; FAO, 2000; Gregory et al., 2002; Matson et al., 1997).
- Consistent with the above, growing populations and increasing land constraints suggest that any future increase in agricultural output on the current path will depend largely on further intensification of irrigation, chemical inputs and mechanization, i.e., ever-greater reliance on fossil energy stocks. This, in turn, implies increased ecological damage (Conforti and Giampetro, 1997).
• Fossil energy supplies may be problematic. Petroleum reserves are finite and global consumption of oil has exceeded discovery for at least 20 years. North American petroleum reserves and production have been in decline even longer and natural gas is now also declining. In response to rising demand, North American domestic natural gas prices have risen steeply and are now 300% or more above those of just a few years ago. Several fertilizer plants have closed or moved operations to Eurasia for reasons of rising costs and diminishing feedstocks. According to various industry experts, global conventional petroleum output is likely to peak within this decade (Campbell, 1999; Duncan and Youngquist, 1999; Laherrere, 2003; Longwell, 2002). Other analysts argue that we still don’t know enough to chose among different energy-supply scenarios or among feasible renewable energy technologies (Hall et al., 2003). Given the uncertainty over suitable substitutes for many uses of liquid, portable fossil fuel, still others are speculating on the implosion of industrial civilization (e.g., Duncan, 1993). Manning (2004) provided an engaging popular account of the crisis.

• Because of market conditions, land degradation, and diminishing returns from inputs, the area of irrigated cropland has declined by 12% and the use of fertilizers by 23% from peak levels. Grain production per capita has been in decline for almost a decade and aggregate food production has fallen for the past 4 years (Pimentel and Pimentel, 1999; Brown, 2004; EarthTrends Data tables compiled from UN-FAO statistics).

• Partially as a result, millions are plagued by hunger. As many as 800 million people remain chronically malnourished and up to 3 billion have inadequate diets. (Contributing to this are patterns of land-ownership and trade that deny impoverished people access to either land for subsistence agriculture or commercially produced food. The poor often cannot participate in food markets for want of cash. Thus, some countries with serious food shortages and nutritional problems are net exporters of luxury cash crops for first world markets.)

The foregoing makes clear that the Green Revolution has by no means been an unqualified success. Food production has increased dramatically in the past 50 years, but this has allowed a 156% increase in the human population. The result is that we now have over 6 billion people, on the way to perhaps 9 billion by the middle of the century, all with rising expectations and all dependent on a biophysical resource base that has been severely eroded by the same agricultural revolution that made their existence possible. Ominously, various important crops in all categories seem to be approaching production plateaus in many parts of the world.

96 Agricultural Biotechnology: Finding Common International Goals
ARE TRANSGENIC CROPS THE SOLUTION?

How has mainstream agricultural science responded to this complexity of problems? Probably the major development in recent years has been the development and rapid introduction of transgenic or genetically modified crops. The most frequently cited potential benefits of transgenic crop varieties include:

- use of fewer, less-toxic or less-persistent pesticides,
- potential for increased crop yields, thus reducing the pressure to convert pasture, woodlands, and other habitats and land-types to agricultural production,
- decreased water use, thus conserving water and providing a buffer against climate change,
- reduced soil tillage and an attendant reduction in mineralization and erosion.

Ostensibly to take advantage of these benefits, transgenic crops (TCs) have become an increasingly dominant feature of the agricultural landscapes of the United States and other countries such as China, Argentina, Mexico and Canada. Between 1986 and 1997, an estimated 25,000 field trials were conducted on more than sixty crops using ten traits in forty-five countries. Worldwide, the areas planted to transgenic crops increased dramatically from 1996 to 1999, from 3 million hectares in 1996 to nearly 40 million hectares in 1999 (Altieri, 2000, 2004). This is no small incursion into the agricultural landscape. According to Altieri (2000):

“In the USA, Argentina and Canada, over half of the acreage for major crops such as soybean, corn and canola are planted in transgenic varieties. Herbicide-resistant crops and insect-resistant crops (Bt crops) accounted respectively for 54 and 31% of the total global area of all crops in 1997.”

Is this significant commitment paying off? Regrettably, the jury is still out. Despite their own extensive survey, Ervin et al. (2000) stated that: “Most studies of the environmental effects of transgenic crops have been confined to laboratories or small fields. The lack of detailed environmental impact data required for commercial approval and releases has hindered risk and benefit assessment efforts.” Nevertheless, some trends do seem to be emerging in two of the key areas pertaining to pesticide use and yield.

As noted, the initial expectation was that farmers who planted TCs would use fewer or less-toxic pesticides, thus reducing the negative ecological effects of intensive agriculture. The rapid spread of these crops suggests that some farmers are benefiting economically, perhaps mainly from simplified weed control. However, various analysts have concluded that, with the possible exception of Bt cotton, there is little evidence that pesticidal and herbicide-resistant TCs require less pesticide. Roundup Ready® soybeans actually require up to 30% more herbicide than the conventional counterpart, despite claims to the contrary (Benbrook, 2001a).
More generally, herbicide-tolerant varieties seem to have modestly reduced the average number of active ingredients applied per acre but have modestly increased the average pounds applied per acre. Depending on the measure used, these crops have either reduced or increased pesticide requirements—either measure alone gives an incomplete picture of the overall impact of herbicide-tolerant varieties on pesticide use and the sustainability of weed-management systems (Benbrook, 2001b). The bottom line is that it is too early to know the long-term impact of transgenic plants on pesticide use—TCs may induce entirely new patterns and volumes of total pesticide use. “Unfortunately, at this stage in crop biotechnology, the cumulative shifts in use of many pesticide compounds are mostly uncertain” (Ervin et al., 2000).

The effect of transgenic varieties on yield is no less ambiguous. Proponents of TCs argue that increased yield would reduce the need for further land conversions for agriculture. However, this simplistic view ignores the multiple possible interactions of different kinds of genetic modification with pest conditions, weather factors, soil types, etc. (Ervin et al., 2000). Keep in mind, too, that the most widely accepted transgenic varieties, such as Roundup Ready® soybeans, were not intended to achieve yield increases. Even in the case of Bt cotton and corn, increased yield projections were based only on improved pest control and results have been variable (Ervin et al., 2000). On the negative side, there is solid evidence that Roundup Ready® soybean cultivars produce 5 to 10% fewer bushels per acre in contrast to otherwise identical varieties grown under comparable field conditions (Benbrook, 2001a). In the longer term, it is possible that transgenes involving the manipulation of basic physiological processes such as photosynthesis will improve yields dramatically, but this will likely be accompanied by complications such as increased demand for water and nutrients. At present, there is no empirical evidence that TCs change water use or tillage requirements.

While the promise of TCs has yet to be unambiguously realized, numerous authors have speculated on the potential for serious ecological damage. Emergent and anticipated problems include (Rissler and Mellon, 1996; Altieri, 2000, 2004):

- spread of TCs threatens crop genetic diversity by simplifying cropping systems and promoting genetic erosion,
- potential transfer of genes from herbicide-resistant varieties to wild or semi-domesticated relatives thus, creating super weeds (a form of genetic pollution),
- herbicide-resistant volunteers become weeds in subsequent crops,
- use of herbicide-resistant crops undermines possibilities for crop diversification, thus reducing agrobiodiversity in time and space,
- vector-mediated horizontal gene transfer and recombination could create new pathogenic bacteria,
- vector recombination could generate new virulent strains of virus, especially in trangenic plants engineered for viral resistance with viral genes,
The net benefits of many transgenics, even to producers, are by no means clear and their widespread use poses a range of threats to food security.

- adverse effects on non-target organisms,
- insect pests are developing resistance to crops with Bt toxin (as they do to synthetic biocides).

In short, the net benefits of many transgenics, even to producers, are by no means clear and their widespread use poses a range of threats to food security (quite apart from any possible risk associated with consuming genetically engineered food). It is telling, in this light, that the transgenic revolution is being developed and promoted by the same corporate interests that brought us the first wave of agrochemically based agriculture. Altieri (2004) argues: “As long as transgenic crops follow closely the pesticide paradigm, such biotechnological products will do nothing but reinforce the pesticide treadmill in agroecosystems, thus legitimizing the concerns that many scientists have expressed regarding the possible environmental risks of genetically engineered organisms.”

In summary, at this stage it seems that (Wolfenbarger and Phifer, 2000):

neither the risks nor the benefits of [GM organisms] are certain or universal. Both may vary spatially and temporally on a case-by-case basis… At the same time there is increasing evidence of significant unanticipated negative consequences to the unchecked spread of transgenics. Our capacity to predict ecological impacts of [GM organisms] is imprecise and [available data] have limitations.

**WHY DO WE STAY THIS ERRATIC COURSE?**

Wall Street science will find only what satisfies Wall Street. The fact that it is championed as sound science makes it no more sound or truthful than a cult leader on an ego trip (Salatin, 2004).

More than a decade ago, a World Resources Institute study compared conventional and organic farming practices in Pennsylvania and Nebraska. In Pennsylvania, conservation cultivation of corn and corn-soybean production eliminated chemical fertilizer and pesticides, cut costs by 25%, reduced erosion by 50% and actually increased yields over conventional norms after 5 years. Researchers estimated that these practices would reduce off-farm damages by $75 per hectare of farmland, and avoid 30-year income losses (present value $306 per hectare) by preventing a 17% loss in soil fertility. All things considered, the resource-conserving practices outperformed conventional approaches in economic value per hectare.
by a two-to-one margin. In flat-land Nebraska, where the costs of erosion are lower, low-input cultivation was slightly less financially competitive than the prevailing high-input corn-bean rotation but was found to be environmentally superior overall (Faeth et al., 1991, cited in WRI, 1992).

This is only one of many studies suggesting that more-sustainable agricultural practices work and can be learned by farmers in developed as well as less-developed countries. Indeed, enough evidence is available to suggest that low-input ecologically based agro-technologies could contribute to food security at many levels.

Just how productive and sustainable agroecological systems are is to some degree still an empirical question. Certainly, as critics of alternative production systems like to point out, there may be lower yields of particular crops than in high-input conventional systems. Yet, as Altieri et al. (2004) argued:

> All too often it is precisely the emphasis on yield—a measure of the performance of a single crop—that blinds analysts to broader measures of sustainability and to the greater per-unit-area productivity obtained in complex, integrated agroecological systems that feature many crop varieties together with animals and trees. There are also cases where even yields of single crops are higher in agroecological systems that have undergone the full conversion process.

Altieri et al. (2004) recognized that some of this apparent advantage may be due to the well known inverse relationship between farm size and production—smaller farms make far more productive use of the land resources than do large farms. Yet, in some situations:

> even medium- and large-scale producers are increasingly making use of the agroecological approach, recognizing the advantages of these principles and techniques over conventional approaches.

If agroecology and other approaches to sustainable agriculture show such promise, why is it that mainstream agro-biotechnology remains steadfastly focused on chemically based agriculture and genetic engineering? Part of the answer emerges from the fundamental “value program” that underpins techno-industrial society. John McMurtry (2004) built the case that:

> the deep causal structure at work in the cumulative environmental catastrophe of our era is the deciding values of the global market economy itself.

The dominant value-system of our contemporary growth-oriented globalizing world is a social construct that philosopher McMurtry (1998) refers to as “the money sequence of value”: “The name of the game of the money sequence of value is to maximize money or money-equivalent holdings as a good in itself...” Money is invested in processes or commodities that lead to more money outputs
for investors in a kind of self-perpetuating economic perpetual motion machine. Since its proponents purport to believe that this system has the potential to enhance human well-being better than any other, it follows that any other value or position that opposes it must be overridden. Dominance of the money sequence of value is thus ruinous to the alternative life sequence of value” (investment in things that sustain life leads to more opportunities for life). The money sequence of value (McMurtry, 1998):

now expropriates and attacks the civil commons at its edges, trunk and roots, ‘privatizing,’ ‘axing,’ and ‘developing’ so that its life-spaces and functions are stripped across society with no sense of loss.

It follows that in this value framework, the decisions of the marketplace are supreme.

McMurtry’s framing of the global market paradigm provides a perfect context for Jack Manno’s explanation of why certain goods become “privileged” in modern societies. Manno (2000) asked:

Why, when it is clearly rational…to do so, can’t we put at least as much attention and resources toward conserving energy and materials as we do toward mining and harvesting more and more?…Why not do as much research into organic agriculture as the fertilizer and pesticide [and TC] industries do on their R&D? Why do we not spend as much on disease prevention as we do on pharmaceuticals and high-tech treatments?

The choices seem self-evident, yet it is just as obvious that modern society is not about to pour anything like the equivalent resources into alternative energy systems, sustainable agriculture, public health, etc., as it does into the prevailing ecologically destructive alternatives.

If anything, the opposite is true: ecologically destructive ways of living are continually spreading into societies and cultures that once managed to live more frugally and in balance with nature. Why? (Manno, 2000).

Manno answered his own question by arguing that in market societies goods with certain qualities tend to be favoured over all others (Table 2). Driven by the money sequence of values, markets automatically work to address every human need and desire with those goods that can most easily be produced for market and sold. Other goods and services—even those that might give more satisfaction and cause less damage—tend to wither and fade away. For example, “soil additives, chemical fertilizers, and insecticides (and we might add GM seeds) are all products patented, packaged, distributed and sold. The farmer who knows and protects the soil from erosion and overuse has as her most important product her knowledge and skill, which cannot easily be packaged and sold” (Manno, 2000). Thus the hard-edged products of commerce dominate agriculture today while the softer intimate knowledge of the land fades from cultural memory.
TABLE 2. SELECTED CHARACTERISTICS OF PRIVILEGED COMMODITIES CONTRASTED WITH THOSE OF NON-PRIVILEGED COMMODITIES (AFTER MANNO, 2000).

<table>
<thead>
<tr>
<th>Attributes of goods and services with low commodity potential</th>
<th>Attributes of goods and services with high commodity potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Openly accessible—widely available; difficult to establish property rights; hard to price and market.</td>
<td>Appropriable—excludable; enclosable; assignable; easy to establish property rights; easily priced and marketed.</td>
</tr>
<tr>
<td>Rooted in local ecosystems and communities.</td>
<td>Mobile and transferable; easy to package and transport.</td>
</tr>
<tr>
<td>Particular, customized, decentralized and diverse; unique to each culture and environment.</td>
<td>Universal, standardized, centralized and uniform; adaptable to multiple contexts.</td>
</tr>
<tr>
<td>Systems-oriented—development occurs in context of wider system; goal is overall optimization; products develop to serve the system.</td>
<td>Product-oriented—development focuses on maximizing output; goal is profit maximization; system is transformed to serve the product.</td>
</tr>
<tr>
<td>Dispersed energy—energy is used and dissipated at the site of the activity or at point of exchange or consumption.</td>
<td>Embodied energy—production is energy intensive; packaging, promotion and transportation add to energy ‘content’ of the product.</td>
</tr>
<tr>
<td>Low capital intensity.</td>
<td>High capital intensity.</td>
</tr>
<tr>
<td>Design follows and mimics natural flows and cycles.</td>
<td>Design resists or alters natural flows and cycles.</td>
</tr>
<tr>
<td>Contributes little to GDP—non-market goods don’t show up in national statistics.</td>
<td>Contributes to GDP—GDP is essentially a measure of marketed goods and the scale of commoditization.</td>
</tr>
</tbody>
</table>
Various material inputs to “traditional” production agriculture—fertilizer, pesticides, irrigation equipment, mechanized tools and equipment—all possess the properties of highly commoditizable goods and services, the kinds so privileged by techno-industrial society and its money sequence of value. Genetically modified seeds and genetic material generally share these qualities, particularly since the courts have supported the rights of firms to patent and licence the use of “their” inventions for profit.

Manno (2000) calls this subtly unconscious process “commoditization”:

At its core, commoditization is the continuous pressure to transform as much of the necessities and pleasures of life as possible into commercial commodities.

Given the nature of the market economic process, it is to be expected that many of the qualities that characterize privileged commodities are precisely the qualities that concentrate energy and materials and do the greatest ecological and social damage.

Even a cursory look at Table 2 confirms that the various material inputs to “traditional” production agriculture—fertilizer, pesticides, irrigation equipment, mechanized tools and equipment—all possess the properties of highly commoditizable goods and services, the kinds so privileged by techno-industrial society and its money sequence of value. Genetically modified seeds and genetic material generally share these qualities, particularly since the courts have supported the rights of firms to patent and licence the use of “their” inventions for profit. Little wonder that the transgenic revolution in agriculture is being brought to us by “the same corporate interests that brought us the first wave of agrochemically-based agriculture” (Altieri, 2004). As Salatin suggested, what passes for “sound science” in the marketplace is that science that adds the most to the short-term corporate bottom line. Contemporary sound science in agriculture may well be “killing” us (Salatin, 2004).

EPILOGUE

According to popular and even much “scientific” belief, the good Reverend Malthus’s dismal theorem has long been put to rest. However, the foregoing analysis suggests that, despite advances in technology, humanity may yet be confronted
The aggregate human ecological footprint of consumption and waste dissipation made possible by abundant energy supplies is 20% greater than the biocapacity of the planet.

with a global food/population crisis in coming decades. The industrial revolution and industrial agriculture greatly increased global food production and staved off starvation for billions in the twentieth century, but hundreds of millions more have yet to join the table, and the human family is expected to grow by an additional 2 to 3 billion in the first half of this century. Meanwhile, increased intensity of crop production has accelerated the degradation of arable soils, irreversibly dissipating thousands of years' accumulations of vital nutrients and organic matter. While irrigation, mechanization and chemical inputs have temporarily made up for productivity losses, these technologies are dependent on fossil fuels that are, in turn, rapidly being consumed.

The second law of thermodynamics cannot be overturned. The much-exalted seemingly vibrant far-from-equilibrium state of the modern human enterprise, and the very existence of today's 6.3 billion people, is possible only because of the prior accumulation of large stocks of natural capital (resource stocks). In particular, since 1850, the plot of human population growth is virtually identical with the plot of fossil energy usage. Unfortunately, the most critical of our natural capital stocks—soils and oil—are rapidly being irreversibly depleted and the dissipated by-products (e.g., carbon dioxide) now threaten to double the damage through climate change. Meanwhile, the aggregate human ecological footprint of consumption and waste dissipation made possible by abundant energy supplies is 20% greater than the biocapacity of the planet (WWF, 2002).

The introduction of transgenic crops is arguably just one more step down the slippery slope toward entropic disorder and systemic chaos.

This situation is not sustainable. To the truly rational mind—not the merely self-interested utility-maximizing economic mind—it would seem to call for a radical change in humanity's relationship to the ecosphere. Ecosystems are self-producing and self-perpetuating, and in the right physical environments they accumulate species, biomass and life-giving nutrients while forever recycling the chemical basis for life. By contrast, industrial agroecosystems are self-consuming quasi-parasitic systems that shed biodiversity, dissipate energy and nutrients and convert natural cycles into terminal throughput. Attempting to maximize pro-
duction of a single variable—the food crop—using an external energy subsidy destroys the structure and functional integrity of the whole. The introduction of transgenic crops is arguably just one more step down the slippery slope toward entropic disorder and systemic chaos.

In these circumstances, we need instead “an agriculture that more nearly mimics the structure and functions of natural ecosystems” (Jackson, 2004). Indeed, we need to extend the concept of biomimicry to the whole-systems level. Species in ecosystems co-evolve in mutual dependence and support. Ecosystems are autopoietic: the relationships among the interacting components—living organisms—are essential for the continued production and functioning of the components themselves (Maturana and Varela, 1987). We humans must learn to be a constructive participant in, rather than a combatant against, the ecosystems that sustain us. Adopting this goal would actually move us toward a much more intensely knowledge-based system of agriculture. Ecologically sustainable agriculture requires a vastly more sophisticated understanding of complex systems theory and ecosystems behavior than does the corporate, high-input, “brute force” production agriculture ravaging the planet today. Ecosystems science should become the agricultural biotechnology of the twenty-first century. Without an evolutionary ecologically based agriculture, our arable lands and soils, our rural families and communities, will continue to languish in a state of siege.

Ecologically necessary and economically feasible, sustainable agriculture based on an agroecological model is also socially desirable for rural areas. The realistic pricing of resources, attention to the ecology of land, and eco-technology implies a return to smaller farms and more labor- and information-intensive practices. The countryside might, therefore, regain population as human labor and ingenuity once more become an important (renewable) factor in primary food production. In this way, sustainable agriculture would help restore an historical cultural landscape through salvation of the family farm and revitalization of dependent communities. Meanwhile, urban society would reap special dividends with the restoration of ecological diversity and beauty to the rural landscape, and through reduced pollution of air, water, and soil and other off-farm impacts. We might even enjoy more-wholesome, safer food.

If Homo sapiens does not learn to live within the means of nature, we will wind up permanently dissipating our habitat.

The motive for the needed revolution is simple and strong. If Homo sapiens does not learn to live within the means of nature, we will wind up permanently dissipating our habitat. Resources degraded, the human enterprise would necessarily plunge toward a new (and dismal) closer-to-equilibrium state. Food production could fall below pre-industrial levels and the human population to fewer than 2 billion.
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William Rees has taught at the University of British Columbia since 1969 and is currently professor in the School of Community and Regional Planning. His teaching and research emphasize the public policy and planning implications of global environmental trends and the necessary ecological conditions for sustainable socioeconomic development.

Much of Dr. Rees’s work is in the realm of ecological economics and human ecology. He is best known in this field for his invention of “ecological footprint analysis,” a quantitative tool that estimates humanity’s ecological impact on the ecosphere in terms of appropriated ecosystem (land and water) area. This research reveals the fundamental incompatibility between continued material economic growth and ecological security, and has helped to reopen debate on human-carrying capacity as a consideration in sustainable development.

Rees is currently a co-investigator in the Global Integrity Project, oriented toward determining the necessary ecological conditions for biodiversity preservation. He has been lectured on his work across Canada and the United States, as well as in Australia, Austria, China, Finland, Germany, Great Britain, Japan, Mexico, the Netherlands, Norway, Indonesia, Italy, Korea, the former Soviet Union, Spain, Sri Lanka, and Sweden.

In 1996, he was awarded a UBC Killam Research Prize in acknowledgement of his research achievements.
I will discuss biodiversity and I will discuss agriculture, but I cannot avoid going into social matters, into cultural matters. Let me begin with a brief background to the great debate. All participants in this conference are participants also in the discussion of world-food problems and we should feel privileged to be involved in this historic debate. A technology boost is coming to biology, and, in turn, biology will be the source of the biggest technology advancement that human-kind has ever gone through. Hence biology has lost its innocence, and we need to understand the background.

**GENETIC SYMPHONY**

Many still have no idea where we should be headed. William Reese gave us a brilliant example of rethinking knowledge-based agriculture. The complexity of genomics research is recognized. Although the interrelationships among chromosomes are known to be complex, even with *Arabidopsis*—one of the best-characterized genomes—we are far from understanding what is going on at the gene level. We are all painfully aware of the rapid growth in knowledge; it is accumulating at such a speed that it is likely that no one in this room would claim to be able to stay abreast of developments even in her/his own field.

Each genome is extremely complex. Genes should not be viewed singly, in isolation, but rather as a concept, working together in a fantastic symphony. By understanding how genes interrelate, the possibilities for progress will be immeasurable; we will move beyond the current phase of single-gene-altered crops—paleogenetics, as I call it—with insect-resistance and herbicide tolerance.
We live in a risk-averse society; although human longevity is increasing, paradoxically many people believe they live under increasing risk.

**RISK PERSPECTIVE**

We live in a risk-averse society; although human longevity is increasing, paradoxically many people believe they live under increasing risk. We should view this aspect from a historical perspective. The introduction of coffee in London met with stiff resistance. Women’s petitions attempted abolishment of coffee shops on the grounds that it caused impotence in their spouses. Pope Clement VIII (1593–1605) took a different tack: “Why this Satan’s drink is so delicious…it would be a pity for the [sinners] to have exclusive use of it. We shall fool Satan by baptizing it and making it a truly Christian beverage.” Thus, ideology was brought to bear. During the great coffee debate the notion of systemic or substantial equivalence was fielded. There was much discussion in that regard, and we now know that coffee contains at least sixteen carcinogens. It would have no chance of being approved as a new beverage today, which illustrates a modern-day schizophrenia about risk. The Greens demand a ban on the release of genetically engineered organisms, because they maintain there is no proof that they are safe, yet they promote the use of cannabis. Joking aside, there is a serious problem here. It is not unreasonable to be concerned over the genetic engineering of plants. Those without anxiety are the fools in my eyes.

*Precautionary “principle” is inappropriate terminology resulting from poor translation within the European Union. Consultation of the original text reveals that it is an “approach.”*

**PRECAUTIONARY APPROACH/PRINCIPLE**

Part of the complexity of the debate results from the use of the precautionary approach in legislation. Precautionary “principle” is inappropriate terminology resulting from poor translation within the European Union. Consultation of the original text reveals that it is an “approach.”

Linear planning processes are insufficient in this debate. A systems approach is needed. We also need to take a step back to gain perspective in this debate. One of
the foremost principles I would make clear is the symmetry of ignorance. As stated already in this conference, as long as scientists try to explain the world with scientific facts alone, we will encounter more and more difficulties; it’s a clash between post-modernism and modernism. I have insufficient time to go into the elements of the systems approach, but we know that this is not functioning today. Look at US corporate entities: they cannot understand why Europeans refuse their soybeans. Scientists working at the bench often feel little social responsibility for what they do and feel no obligation to debate the issues with the public.

Everyone fond of Italian food has eaten spaghetti produced by gamma-irradiation of the whole genome of wheat.

**MANIPULATION OF EVOLUTION**

Let us go to the heart of the matter: with respect to biodiversity, we should address the argument of the manipulation of evolution rationally and realistically. It does not seem to be generally understood that pollen drift did not begin with the engineering of transgenes. But, because non-containment of transgenes is now an issue, it is likely that the next generation of transgenic plants will not result from complex manipulations for drought resistance, for example—which will take 5 to 10 years—but with non-alien genes. Useful traits will be taken from progenitor landraces and restored to modern cultivars of the same species. If you think that genes are being transferred for the first time across hybridization barriers, you would be wrong; it has been done for years with protoplast technologies. And if you think that we did not manipulate genomes artificially before genetic engineering you would also be dead wrong. Everyone fond of Italian food has eaten spaghetti produced by gamma-irradiation of the whole genome of wheat. This is “Frankenstein”—if you ask me—but it is not genetic engineering. It has been used hundreds of times to produce superior cultivars. The FAO Web-site shows a list of over 500 cultivars produced by gamma irradiation. Yet, although we don’t know what we have done to these genomes, we eat the products without reservation. In fact, not even a red nose has resulted.

There is a common misperception that Golden Rice™ is uniquely artificial; in fact, the parent cultivars of Golden Rice™ were already artificial. Figure 1 was provided by Ingo Potrykus; each “@” sign indicates a breeding event in the pedigree, the result of each of which is totally unpredictable. If safety rules for transgenic crops were applicable, a hundred years of probation and safety tests would be needed. Although the normal process of breeding and selection involves many unpredictable steps, fortunately, pragmatism has prevailed.
One-sided views are inappropriate in this great debate. For instance, when Charles Benbrook claimed that more pesticides are used with transgenic crops he made two mistakes. First he followed the rule that you should believe only the statistics you have falsified yourself; it has been shown that his figures are 20% too high. The bases of all statistics should be examined carefully. Second, he failed to take toxicity as the critical parameter. Toxicity is reduced in conjunction with Roundup Ready® cultivars. Even if it’s from Monsanto it is less toxic, I’m sorry.

In the monarch butterfly case it was shown that no differences exist between Bt and non-Bt maize fields. If I were a non-target insect, I would prefer to visit a Bt field because there would less likelihood of being showered with pesticide. But, to be honest, I would most prefer to vacation with an organic farmer.

That Bt is toxic to certain classic non-target insects is a myth. In a 2004 publication Romeis et al. came to the conclusion that the classic studies of Hilbeck et al. (1998) were done with the wrong insects (half dead), with the wrong concentrations and with the wrong statistics. We should be careful in interpreting the scientific literature.

Figure 1. The pedigree of rice cultivar IR 64.
Mutually contradictory data have been published in peer-reviewed journals from a number of studies on maize pollen deposition on leaves. This is not to suggest that such experiments on pollen deposition have been done with the wrong methods, but the data have demonstrated regional and seasonal differences; sometimes firm conclusions are impossible from so-called exact scientific results. Care in interpretation is needed. Dr. Reese made that very clear in his discussion of ecosystems.

Gene flow is not new; it’s an important component of evolution.

We found no problem with barley, wheat, rye, potato, clover, maize, but we did identify problems with alfalfa and its wild relatives and the grasses of course; and I would like to put lettuce and carrot behind bars!

GENE FLOW
Gene flow is not new; it’s an important component of evolution. Careful attempts to measure pollen drift have yielded highly variable data from cultivar to cultivar and from year to year. In Switzerland we have developed, together with Dutch groups, a method of deriving data from hybrids in herbaria, which is a curious approach for bench workers. We used a statistical approach—I won’t dwell on the morphometrics and numerical taxonomy—to quantify gene flow to wild relatives of nineteen crops in Switzerland: we found no problem with barley, wheat, rye, potato, clover, maize, but we did identify problems with alfalfa and its wild relatives and the grasses of course; and I would like to put lettuce and carrot behind bars! These data, accumulated over many decades, show that seed-producing hybrids are possible. This is agriculturally relevant and more important than producing hybrids by embryo rescue. These findings will soon be reflected in Swiss law.

Apomixis—development of seeds without pollination—offers the most effective means of precluding gene flow. Although some 10% of the wild flora have this capability, its reliable induction in crop plants is proving to be difficult.

NEED FOR VISION
We need knowledge-based agriculture and you at the University of Guelph are making significant contributions in this regard, and I am glad to have been invited
here. I am impressed by your publications record and all the things you are doing here. But we also need vision. As already stated, we need to seriously consider organic farming strategies. A 21-year trial in Switzerland—comparing organic and conventional farming systems—revealed 30% to 40% more earthworm biomass and 50% to 80% higher earthworm density in the former. Clearly, positive effects of organic strategies on soil fertility merit attention. Organic farming should not be the brunt of jokes. (On the other hand, insect-resistant potato would be a wonderful thing to have.)

People in other countries must be free to decide which technologies they wish to adopt and adapt. Progress is not always defined in terms of new technologies. Local traditions are important and we should refrain from corporate and eco-imperialism. Neither should we joke about the precautionary principle; we should develop it as a systems approach, a discursive approach, an open-minded approach. I have debated Buddhists, Zen Buddhists, abbots of Catholic monasteries and Amish farmers, and, in my experience, spirituality goes hand-in-hand with open-mindedness and genuine curiosity. After a 2-hour discussion with Amish farmers, they agreed to plant transgenic crops; Monsanto happily supplied the seed. They tried them out and have adopted them. My best such encounter was with a noble and dignified teacher of the Dalai Lama when he was en route to Hollywood for the premier of Seven Years in Tibet; we had a wonderful discussion. Three world views need to be taken into account:

• through the eye of the flesh—the level at which scientists generate data;
• through the eye of the intellect—the more intelligent scientists view their work in context and ask themselves, “What am I doing here?”;
• through the eye of the spirit—which cannot be intellectualized, but must be felt and practiced.

I believe that a “lacuna” exists in our society, illustrated by the fact that organo-transgenic crops—combining the potential of precision-biotechnology with organic approaches—should be our target. Data generated for length of time of quail chicks to satisfy daily nutritional requirements showed that they foraged for 4.2 hours under no-till herbicide-tolerant soybean whereas they had to forage for 22 hours per day in conventionally tilled soybean fields. Clearly, ecology and herbicide tolerance can be positively correlated.

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KLAUS AMMANN has served as director of the Botanical Garden at the University of Berne, Switzerland, since 1996. As an honorary professor at the university, he teaches plant systematics and evolution, and biogeography. He also teaches air-pollution biomonitoring at the Federal Institute of Technology, Zurich.

Dr. Ammann’s research interests encompass the chemotaxonomy of macro-lichens, calibrated biomonitoring of air pollution with lichens, molecular systematics of lichens, ethnobotany in Jamaica, and ecological monitoring in Bulgaria. He is involved also in ecological risk assessment of vertical gene flow in Switzerland, and in measuring gene flow of the Brassicaceae in Europe as the Swiss coordinator. In collaboration with the United Nations Industrial Development Organization (UNIDO) he is assembling a Compendium on Risk Assessment Research and is a participant in the Global Initiative on Education in Biotechnology.

Ammann contributed to reports on The Impact of Agricultural Biotechnology on Biodiversity and on Systems Approaches to Biosafety.

His committee work includes chairing the European Group of Plant Specialists, serving as a member of the coordination group of the European Science Foundation on risk assessment of transgenic crops, and membership of the Biosafety Committee of the Government of Switzerland.
Agricultural Biotechnology: Finding Common International Goals
We humans live on a finite planet. Yet, our numbers have been increasing exponentially for thousands of years and continue to do so. At the turn of the century we numbered over 6 billion (United Nations, 1999). During the early 1980s, the human ecological footprint (Wackernagel and Rees, 1996) surpassed Earth’s capacity to maintain our current lifestyles and, by the end of the twentieth century, it was estimated that it had exceeded the bio-capacity of the planet by some 20% (Rees, 2002; WWF, 2002; Wackernagel et al., 1999; 2002a, b). In short, we now require more than 1.2 planet Earths to support present conditions. By 2050, the United Nations predicts that the human population will have increased to about 9 billion (United Nations, 2003).

The problems facing the planet—or, more precisely, the human species—are well documented and have been discussed in previous National Agricultural Biotechnology Council (NABC) Reports (e.g. Kirschenmann, 2003). As the global human population grows, resources (especially non-renewable) continue to be depleted and the environment becomes increasingly degraded (e.g. Meadows et al., 2004). Our unsustainable practices include the clearing of forests (Pimm, 2001), the loss of productive soils (Chesworth, 2004; Jackson, 2004), and the overexploitation of fisheries (FAO, 2002a; Pauly et al., 2002), all of which contribute to the on-going loss of biodiversity that some have characterized as the “sixth extinction” (Leakey and Lewin, 1996; Eldredge, 2001; Ward, 2004). In addition, we are interfering with fundamental evolutionary processes through the exploitation of natural resources (e.g. selective hunting, such as trophy hunting, fishing, and forestry), the introduction of exotic, alien, or non-native species, and, most recently, through the production and release of genetically modified (GM) organisms into the environment (S.J. Holt, pers. comm.). We are also depleting reserves of oil and natural gas (P. Roberts, 2004), increasing greenhouse-gas emissions and contributing to global climate change (IPCC, 2001). Superimposed
on all these realities is the growing social inequity and economic disparity between the North and South, the so-called developed and developing worlds, respectively (e.g. Elliott, 2001). Of particular relevance is the fact that millions of people (some say billions), most of whom live in the developing world, are going hungry and suffer from malnutrition (e.g. Mittal, 2000; Pimentel, 2004).

In this symposium, we have been asked to consider the prospects for reducing the agricultural eco-footprint. In order to attempt that, I will first try to place agriculture into a broader global ecological context. I will then consider the “problem” of feeding the world’s hungry, including possible roles for agricultural biotechnology. Finally, I will examine the prospects for reducing the agricultural eco-footprint, given our evolutionary legacy as Darwinian animals. I will end on a note of optimism: that humans really can change the current situation, if there is the collective will to do so.

AGRICULTURE AND THE FIRST “LAW” OF ECOLOGY

If there are “laws” in ecology, one would be that “everything is connected to everything else” (Commoner, 1971). Agriculture is a case in point (Figure 1). Human
animals have practiced it for some 10,000 years; it obviously has effects on both non-human animals and plants that collectively constitute what these days we call biodiversity. Agriculture also affects the quality and quantity of soil and the quality and availability of water (Pearce, 2004) and, in recent decades, it has used increasing amounts of “fossil sunlight,” including oil and natural gas, to maintain soil fertility and to increase food production. The latter results in the release of increasing amounts of carbon dioxide to the atmosphere, adding to the accumulation of greenhouse gases, which are thought to be contributing to climate change on a global scale.

We can accept that there are problems and look for potential solutions.

Given the problems associated with the human condition outlined in the introduction and reiterated in relation to agriculture in the preceding paragraph, we have at least two options. We can deny that there are problems, following the examples of the late Julian Simon (e.g. 1992) and his modern disciple, Bjorn Lomborg (2001; EAI, 2002). Alternatively, we can accept that there are problems and look for potential solutions. I will deal only with the latter alternative.

One Putative Solution

One suggested “solution,” widely embraced and promoted since 1987, is the concept of “sustainable development.” Formally introduced in the 1980 World Conservation Strategy produced by the International Union for Conservation of Nature and Natural Resources (IUCN), in conjunction with the United Nations Environment Programme (UNEP) and the World Wildlife Fund (WWF), it was brought to the public consciousness by the 1987 report of The World Commission on Environment and Development (WCED), entitled Our Common Future. (This widely cited and influential document is commonly referred to as the Brundtland Report after its chair, Dr. Gro Harlem Brundtland, the former prime minister of Norway.) The WCED report was followed by a second—almost forgotten—world conservation strategy, Caring for the Earth (IUCN, 1991), which attempted to insert the ideas of sustainable development back into a conservation agenda (Robinson and Redford, 2004). But what Caring for the Earth really did was to subsume “conservation under the development agenda and [confuse] the distinct goals of conservation and development” (Robinson and Redford, 2004; Robinson, 1993).

The WCED (1987) defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (p. 8). This definition has been criticized not only because it is circular (development defined in terms of development), but also because
it does not specify precisely what it is that needs to be sustained (e.g. Lavigne, 2002). Some commentators, like Robinson (2002), regard the lack of a precise definition as a virtue, termed “constructive ambiguity.” Being vague and ambiguous allows so-called “stakeholders” with very different values and objectives to sit at the same table and come to some “agreement” about “sustainable development.” The fact that each participant interprets the words quite differently and has quite different—and, often, diametrically opposed—views on what needs to be done really doesn’t seem to matter.

Among many others, I take quite a different view, agreeing with those, like Chesworth et al. (2001), who characterize sustainable development as the oxymoron of the latter twentieth and early twenty-first centuries (Lavigne, 2002). Unlike Robinson (2002), I do not see the ambiguity implicit in the term sustainable development to be constructive in any redeeming way. Rather, I argue that the vagueness of the term actually facilitates something called “deceptive ambiguity” (Lavigne, 2002). To my mind, sustainable development is actually part of a “conspiracy”—in the words of my colleague Sidney Holt—“devised to maintain capitalism as the only and permanent economic system,” and to allow the developed world to maintain and increase the size of its ecological footprint at the continuing expense of the developing world (Lavigne, 2002). Viewed in this light, sustainable development really is “a new world deception,” something that Willers (1994) recognized and described rather early in the game (for a detailed critique of the concept, see Beder, 1996).

If such a view seems overly harsh, consider what has happened in the world, post-Brundtland. We have managed largely to sustain economic growth in the developing world. Meanwhile, according to the World Bank, the gap between rich and poor nations has widened to the point that 20% of the world’s population now controls 80% of the wealth (Elliott, 2001). Furthermore, somewhere between 800 million (Mittal, 2000; http://www.monsantoafrica.com) and 3 billion (Pimentel, 2004) people remain hungry and malnourished. After the 2002 United Nations conference on environment and development in Johannesburg, one observer went as far as to suggest that “sustainable development is dead” (Bruno 2002). Nonetheless, many world leaders, among others, continue to promote it as the solution to the world’s ills (Lavigne, 2002).

With this as background, let’s move on to the topic at hand: agriculture’s contribution to the current state of the human condition, and how we might reduce the size of the agricultural eco-footprint.

**The Nature of Agriculture**

Non-agricultural scientists often view agriculture quite differently from many who work in the field. Niles Eldredge (2001)—an evolutionary biologist, best known perhaps for his work with Stephen J. Gould on punctuated equilibria (Eldredge and Gould, 1972)—suggested, for example, that “agriculture represents the single most profound ecological change in the entire 3.5 billion-year history of life.”
While Eldredge’s claim may be open to debate (but, see Ward, 2004), Wes Jackson’s (2004) more modest claim that “our farming has never been sustainable” is difficult to refute. Jackson, a geneticist by training, argues that our agriculture, based as it is on annual crops, is an historical accident that replaces natural ecosystems with monocultures, contributes to the on-going loss of biodiversity, reduces soil fertility, leads to soil erosion, and promotes environmental contamination through the application of human-made pesticides, fungicides, and herbicides. According to Jackson, some 38% of the world’s agricultural soils are now degraded. The logical extension of his argument appears in a commentary by Ward Chesworth (2002), a geochemist: “The fact that we have not yet invented a truly sustainable agricultural system means that we have not yet achieved a truly sustainable civilization.”

The solutions to the problems described above are not trivial, but they do seem quite obvious. We must limit our numbers or nature will impose its limits on our quality of life, our numbers, or our very existence as a species. We must also reduce our consumption of the biosphere (especially those of us in the developed world) and thereby reduce the size of the human ecological footprint, including, of course, the agricultural eco-footprint.

A dilemma (noted previously) is that the human population continues to grow, especially in the developing world. So, can we even contemplate feeding the world’s hungry without increasing further the size of the agricultural eco-footprint?

The “food shortage” problem is actually one of distribution and affordability

FEEDING THE WORLD’S HUNGRY

Not being a specialist in agriculture, I did some research on the Internet to see what ideas had been put forward for solving the problem of feeding the world’s hungry. According to the non-governmental organization, the FoodFirst Institute for Food and Development Policy, food production is actually not the problem per se; we already produce enough food to feed the world’s 6 billion inhabitants (Mittal, 2000). In fact, 78% of countries reporting child malnutrition actually export food. The “food shortage” problem is actually one of distribution and affordability.

Mittal’s claims were substantiated in a report from the Food and Agriculture Organization of the United Nations (FAO, 2002b): there is not only enough food for the present, but for the future as well. And, of particular relevance to an NABC

1On a visit to Ireland following NABC 16, I learned that such occurrences are nothing new. During the Irish potato famine of the mid-1800s—when millions starved to death or were forced to emigrate—Ireland exported food (O’Grada, 1993; Woodham-Smith, 1991).
symposium, there is enough food without GM crops. (Indeed, GM crops, livestock, and fish were omitted from the FAO analysis due to ambiguities over long-term promise, safety and consumer acceptance.) According to the FAO, poverty and poor food distribution will continue to limit access to food in some countries for the foreseeable future (also see Union of Concerned Scientists, 2000).

Contrary views are also to be found. According to Hassan Adamu—at the time, the Nigerian Minister of Agricultural and Rural Development—agricultural biotechnology holds great promise for areas of the world like Africa where poverty and poor growing conditions make farming difficult: “GM food could almost literally weed out poverty” in Africa and “without the help of biotechnology, many people will not live” (Adamu, 2000).

And, according to Monsanto (http://www.monsantoafrica.com), agricultural biotechnology can increase crop yields, provide more nutritious foods, and reduce costs to farmers, in an environmentally sustainable manner. The corporation goes on to say that the biotechnology revolution must not bypass Africa (as did the Green Revolution of the 1960s and 1970s; Manning, 2004a). In light of my earlier comments, it was interesting to note that “Monsanto welcomes the opportunity to be a partner for progress, working toward the sustainable development of farmers in Africa and across the world” (emphasis added).

A more recent report from FAO (2004) seems to reveal a change in perspective from that offered in 2000. By 2004, FAO was of the view that biotechnology holds great promise for agriculture in developing countries. But its newly found enthusiasm for GM crops was tempered with several caveats. Poor farmers, FAO noted, can benefit only from the products of biotechnology if they “have access to them on profitable terms.” (Again, we have an example of the distribution and affordability problems mentioned earlier.) These conditions, the report continues, are being met only in a handful of developing countries. The report also notes that the basic cash crops of the poor—cassava, potato, rice and wheat—actually receive little attention from practitioners of agricultural biotechnology in the developed world. This is, of course, entirely consistent with the assessment of sustainable development above.

The differing opinions outlined above notwithstanding, the fact is that we continue to look to increasing agricultural production as the means for reducing both hunger and poverty around the globe (e.g. ADM, 2004; Watson and McIntyre,
2004), and for accommodating the expected increase in the size of the human population over the coming decades. As in the past (Donald, 2004; P. Roberts, 2004), increases in agricultural production can be achieved in two ways: we can increase the area of land planted (e.g. Meadows et al., 2004) or we can—in theory at least—increase the yield achieved per unit area (e.g. Donald, 2004; Meadows et al., 2004).

If we take the first approach, we must clear more forests, especially in the developing world, thereby exacerbating the depletion of wildlife (as in the on-going bushmeat crisis in Africa and Latin America; Robinson and Bennett, 2000). By 2050, Tilman et al. (2001) estimate that 10^8 ha of land may be cleared for cultivation in the developing world, particularly Latin America and sub-Saharan Africa. This is an area approximately equal to that of all of the remaining tropical forests (Mayaux et al. 1998). In addition to the concomitant loss of biodiversity—tropical forests are characterized by high species diversity (Donald, 2004)—forest clearance by burning already accounts for about 25% of the total CO2 emissions, making it a major contributor to global climate change (Newmark, 1998).

The second approach, continuing to intensify production—to the extent that further increases are even possible (Meadows et al., 2004)—will require ever-increasing inputs of energy. Remember the second law of thermodynamics (Rees 2004) and Barry Commoner’s (1971) reminder, reiterated by Garrett Hardin (1977): “there is no such thing as a free lunch.” For every calorie of food produced by intensive agriculture, we already invest ten or more calories of energy (Jones, 2003), much of it in the form of fossil fuels (Manning, 2004a, b). And we are rapidly running out of fossil fuels (P. Roberts, 2004).

Further, if GM plants and animals continue to be part of the equation, then any increases in the productivity of intensive agricultural systems will be accompanied by the introduction of truly alien species into the environment. Noting that “naturally occurring” introduced, non-native species already represent one of the major threats to endemic species (e.g. Groombridge, 1992; Simberloff, 2000), one can only begin to speculate on the potential impacts of GM organisms on natural biodiversity in the years to come.

Regardless of any anticipated benefits from biotechnology, such as the reduced use of fertilizers and environmentally contaminating chemicals, increasing production in an agriculture based on annual crops (whether assisted by biotechnology or not) seems destined to increase, rather than decrease, the size of the agricultural eco-footprint (Jackson, 2004). That may even be the not-so-hidden objective, if we may take literally the promotional materials of one prominent agricultural biotechnology company (ADM, 2004). In the center of one page, there is a globe, oriented—tellingly—to feature the United States. Superimposed over the planet in white lettering are the words, “What if we looked at the world as one giant farm field?” Now that really is increasing the size of the agricultural eco-footprint. At the bottom of the advertisement are the alarming (to an ecologist, at least) words: “The Nature of What’s to Come.”
REducing the Size of the Agricultural Eco-Footprint

The promotional material referred to in the preceding paragraph also tells us, “Nature has answers” and asks the question, “Is anyone listening?” It is Wes Jackson’s (2004) view, in fact, that nature does have some answers. But the answers he is referring to are quite different from those implied in the ADM materials. I suspect, however, that he too would ask whether anyone is really listening.

Wes Jackson argues that we can make agriculture sustainable only by applying ecological principles. We must reverse the accident of history and develop an agriculture based on perennials and dependent solely on contemporary sunlight (as opposed to fossil fuels). It might even use agricultural biotechnology to hasten its realization. Such an agriculture would reduce soil degradation and loss through erosion, and would be ecologically sustainable.

Jackson (2004) argues that we can make agriculture sustainable only by applying ecological principles. We must, he says, reverse the accident of history and develop an agriculture based on perennials and dependent solely on contemporary sunlight (as opposed to fossil fuels). It might even use agricultural biotechnology to hasten its realization. Such an agriculture would reduce soil degradation and loss through erosion, and would, in his view, be ecologically sustainable.

In theory, Jackson’s proposal sounds convincing. In practice, it may be difficult to achieve. He estimates, for example, that it would take about 50 years to complete the transition from an agriculture based on annuals to one based on perennials. And, if we were successful, such a transition might buy Homo sapiens another 10,000 years (“maybe”), and result in a carrying capacity of about 2 billion people (one-third of the 2004 world population and two-ninths of the population anticipated within fifty years (Jackson, 2004; Lavigne, 2004a).

In my opinion, Jackson’s vision will be difficult to sell. It will be opposed by traditional agriculture, including seed suppliers, and fertilizer and pesticide producers; organic farmers; the producers of annual GM crops; and their existing (and well established) lobbies. It will also be resisted by politicians with their short time horizons (4 to 5 years in western democracies) (Lavigne, 2004a).
A Way Forward

There is, however, a way forward. First and foremost, we need to identify the real problems. In the case of feeding the world’s hungry, we must decide whether the real problem is a food shortage or a distribution/affordability issue. Once the real problem has been identified, we must then work toward developing solutions that actually deal with it. For example, we currently have a global over-fishing problem. One question today is whether we need to cull marine mammals (including whales) because they are draining the oceans of fish (Tamura and Ohsumi, 1999; Lavigne, 2003) or do we work to make fishing an ecologically sustainable activity?

We also have problems with overexploited wildlife populations and an increasing number of endangered species. Do we provide increased protection for endangered species with a view to halting their decline and promoting their recovery, or do we promote their commercial consumptive use and free trade in order to “save” them (Child and Child, 1990; Baskin, 1994; SASUSG, 1996; Lavigne, 2004b; Lavigne et al., 1999)?

In the case of the human food crisis, do we work to solve the distribution problems, or do we recommend the development of GM foods, recognizing—among other things—that the delivery of GM technology is plagued by the same distribution and affordability issues as the delivery of food. Similarly, where we have problems of economic disparity and social inequity, do we consider implementing real debt-reduction schemes, or do we simply maintain the status quo?

If society wants to find solutions to real problems, the answers to the above questions should be self-evident. But more can be done if we really want to change the unsustainable practices of the last 10,000 years. One suggestion that has been made frequently over the past 50 years is the need for a new conservation ethic. This idea was central to Aldo Leopold’s (1949) Land Ethic, in which he argued that we must adopt a more ecological and eco-centric approach to our dealings with the rest of nature. In other words, we must recognize that humans are part of nature, not outside of it. Generally, we must increasingly incorporate ethics into science and technology (e.g. Lynn, 2004). We must also recognize and accept that nature has intrinsic and other values and, to paraphrase Eugene Odum (1971), that money is not the common currency of ecosystems (Lavigne, 2004b). In addition, we must reduce (rather than promote) human population growth; get treatment for our addiction to consumerism (e.g. Gore, 1992); and adopt truly precautionary approaches to conservation (Lavigne, 2004b).
We should also abandon the idea of sustainable development, including the simple-minded, three-legged stool model that depicts sustainability as being perched on legs of environment, economy and social equity (for a discussion, see Dawe and Ryan, 2003). In such a model, economic considerations always take priority over environmental (and, indeed, social) concerns. Yet, the reality is that we cannot have a healthy economy or ever hope to enhance social equity unless we have—first and foremost—a sustainable environment (Dawe and Ryan, 2003).

Conservation in the twenty-first century must also recognize that different regions of the world have different values, objectives and needs (Menon and Lavigne, 2004). Conservation, therefore, must become “a more elastic concept, stretching to meet the distinct social contexts, cultural matrices, and political environments in which it must function” (Miller, 2001). The latter, of course, is the antithesis of globalization, the path down which the world community currently gallops.

And, in keeping with the theme of NABC 16, Finding Common International Goals, we must, as Gifford Pinchot—arguably the father of the modern conservation movement—said over 50 years ago, “see to it that the rights of people to govern themselves shall not be controlled by great monopolies through their power over natural resources” (Pinchot, 1945, cited in Miller, 2001).

**Reasons for Pessimism**

While there does seem to be a way forward, the fact remains that there are a number of reasons for doubting that much progress will be made in finding solutions to our global problems and, in particular, in reducing the size of the agricultural eco-footprint. These reasons relate to our evolutionary legacy: the nature of individual human animals, and—not unrelated—our group behavior in social situations.

**Our Evolutionary Legacy as Darwinian Animals**

The first reason for doubt lies in our evolutionary legacy. We are good Darwinian animals concerned primarily with selfish, self-interest. Altruistic behavior required to solve many of our global problems does not come easily to Darwinian animals (Lavigne 2002).

In addition, all life forms seem to practice deception in one form or another. In the case of human beings, however, we appear to have elevated the art to include self-deception. Indeed, we seem to have evolved what some academics call “Machiavellian intelligence” (Whiten and Byrne, 1997). One of the unfortunate consequences of Machiavellian intelligence, especially in the present context, is that we have “considerable capacity for self-delusion when the truth is unpalatable” (Gaskin, 1982).

Let me give one example where self-delusion plays a role in the current situation. As a species, we have difficulty coming to grips with our individual mortality. Rather than confront our limited life spans, most human societies have developed as myths to get around the issue. These myths take a variety of forms, but almost
invariably involve a “life-after-death.” How can a species in which individuals deny their own mortality even begin to contemplate the death (i.e., extinction) of our entire species (Orr, 2002)? Personally, I don’t think we can. But even if we could, it is unlikely that we will. The possibility of our extinction—well, actually, its inevitability—is simply too far down the road, i.e. beyond our own lifetimes and those of our children and grandchildren, to disturb us very deeply or keep our attention for very long.

The Behavior of Humans in Groups

According to Whiten and Byrne (1997), “The evolution of [human] intellect [including Machiavellian intelligence] was primarily driven by selection for manipulative, social expertise within groups, where the most challenging problem faced by individuals was dealing with their companions.” It is not surprising, therefore, that further evidence of deception and self-deception becomes evident when one examines even superficially the behavior of humans in groups. I discuss two examples below: the behavior of governments and corporations, the two most powerful institutions in the modern world.

Let’s begin with governments and examine the practice of politics. Politics is “bloodless conflict among individuals, groups, and nations...among alternative values, or...competing visions of what is 'good' ” (Donovan et al., 1981). Politics is also “the father of lies. In political arenas...the participants will distort the advantages of their positions and the disadvantages of their opponents.” Fair enough, but “they will [also] shade the truth—first for their audiences; then in many cases, for themselves” (Donovan et al., 1981). As noted previously (Lavigne 2002), shading the truth for their audiences is deception; Byrne and Whiten (1997) would call it “tactical deception.” Shading the truth “for themselves” requires self-deception.

Of course, this sort of behavior is to be expected. Machiavelli (1469–1527) long ago described the need for such deceptive behavior among political leaders in his classic work The Prince (see Bull, 1961). But what perhaps is less well understood are the consequences that often emerge from such group behavior.

The late historian, Barbara Tuchman (1984), for example, described a “phenomenon... noticeable throughout history: the pursuit by governments of policies contrary to...the self-interest of the constituency or state involved.” She termed this phenomenon “wooden-headedness,” which, she wrote, “plays a large role in government...acting according to wish while not allowing oneself to be deflected by facts.” I expect that the pursuit of continued economic growth, sustainable development, and an unsustainable agriculture in a finite world, will one day be recognized as examples of twenty-first century wooden-headedness.

Now let’s turn to modern corporations. Like governments, corporations are made up of human beings and so provide another opportunity to examine human group behavior (Achbar et al., 2003; Bakan, 2004). Corporations, like individuals, are characterized primarily by selfish self-interest. They are concerned, first
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and foremost with their shareholders and with profit-maximization. The bottom line is more important than the public interest. Generally, they exhibit no moral conscience (as a number of high profile recent events attest). Indeed, if corporations were people, their behavior would be seen to exhibit all the traits of a prototypical “psychopath” (Achbar et al., 2003; Anon., 2004; Bakan, 2004). The analogy is not as stretched as it might seem at first glance. Through an accident of history, corporations—in the United States at least—have the same rights and legal standing as individual citizens (Bakan, 2004). In a remarkably constructive review of the Achbar et al. film, The Economist’s parting shot was that the “infinitely more powerful…modern state has the capacity to behave…as a more dangerous psychopath than any corporation can ever hope to become” (Anon., 2004).

Maybe so, but either way, when you put a number of selfish, self-interested individual Darwinian human beings into a group (e.g., have them form a government, or work together in a bureaucracy or a corporation) something that appears quite un-Darwinian typically emerges: decisions that ultimately act against (rather than promote) the collective self-interest of the group.

WHEN WILL THINGS CHANGE?

It seems unlikely that we humans will overcome our self-delusional tendencies and come to grips with the reality that our ecological footprint (including our agricultural eco-footprint) exceeds the capacity of the planet to support us.

The world’s dominant institutions—governments and multi- and trans-national corporations—continue their blind pursuit of increasing economic growth and increased profits. Today, it is difficult to imagine how individuals and nongovernmental organizations who recognize the folly in such policies can really do anything to change the course of history. But, as several authors have noted recently, they probably can, if only they have the will to do so. While governments and corporations may represent the two most powerful institutions in the world today, there is a third potential power broker: people.

Indeed, modern society can be viewed as having three realms: the economic, the political and the cultural (Perlas, 2000). On the world stage, the economic realm is the purview of international corporations and three major international organizations concerned with development: the International Monetary Fund, the World Bank—both established by the West following World War II—and the World Trade Organization, which emerged out of the General Agreement on Tariffs and Trade (GATT) in the mid-1990s (Parrish 1999). Governments, of course, dominate in the political realm. That leaves the cultural realm and it is occupied—in Perlas’s scheme—by civil society, which comprises individual human beings [for independent but apparently complementary views on this topic, also see Dowie’s (1995) discussion of the “fourth wave” of the environmental movement—grassroots activists—and Chomsky’s (2003) comments about public opinion, which he terms the “second superpower”].
While it is obvious that corporations and governments currently have the power and are in control of the world situation, individual human beings also have power, should they choose (or be allowed) to exercise it. In democratic societies, at least, they have power in the political realm because they cast the votes that elect the politicians. Governments (not to mention political parties and individual politicians) really have only one overriding goal and that is to be elected (or re-elected). Consequently, they are reactive—as opposed to being proactive—which explains why they spend so much of the people’s money monitoring public opinion. Al Gore put it as succinctly as anyone, before he became the Vice President of the United States. “When enough people insist upon change to embolden the politicians to break away from the short-term perspective,” Gore predicted that “the political system will fall over itself to respond to this just demand that we save the environment for future generations” (cited in Lavigne, 1992).

Corporations are just as vulnerable as governments to public pressure, but in the economic realm consumer behavior in the marketplace counts rather than votes. If no one buys their products, they lose their market-share, their profits drop and their shareholders get anxious. Eventually, they respond in predictable and understandable ways and bow to public pressure.

A recent and relevant example of how this works may be seen in Monsanto’s decision to delay further development of Roundup Ready® wheat (Monsanto, 2004). News stories, columns and op-ed pieces (e.g. McCallum, 2004; O. Roberts, 2004; Scoffield, 2004) tell us that it was a “calculated business decision” influenced by “public opinion.” In this particular instance, public opinion was shaped—in large part—by the Canadian Wheat Board, grower and consumer resistance, and by international political pressure from places like Europe and Japan. At the end of the day, the decision was made because of poor market conditions now and in the foreseeable future.

There are increasing numbers of examples where the power of global civil society (or public opinion) has shaped events on local, regional and global scales.

There are increasing numbers of examples where the power of global civil society (or public opinion) has shaped events on local, regional and global scales. Examples include the civil rights and women’s movements of the 1960s (Chomsky 2003), and the environmental movement during its heyday of the 1960s to 1980s (Dowie, 1995). A more recent example was the derailment of the Multilateral Agreement on Investment (MAI), perhaps one of the first examples where the power of the people was mounted using the Internet (e.g. Shah, 2000, 2003).
Noam Chomsky recently wrote, “One can discern two trajectories in current history: one aiming toward hegemony [i.e. power], acting rationally within a lunatic doctrinal framework as it threatens survival; the other dedicated to the belief that ‘another world is possible’” (Chomsky, 2003). My parting question is whether society will remain uninvolved, complacent and silent [remember Richard Nixon’s (1969) “silent majority”?], and accept the “lunatic doctrinal framework” that currently threatens human survival. Or will it say enough is enough, and demand change, in the belief that “another world” really is still “possible”?

Either way, it will provide another test of Suroweicki’s (2004) hypothesis about the “Wisdom of Crowds.” He argues that “large groups of people (and here, I’m thinking of Perlas’s civil society) are smarter than an elite few (governments and corporations)—no matter how brilliant—better at solving problems, fostering innovation, coming to wise decisions, even predicting the future.” My earlier observations about the emergent behavior of humans in groups notwithstanding, we can only hope he is right.

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Agricultural Biotechnology: Finding Common International Goals


DAVID LAVIGNE has studied seals, sea lions and walruses (pinnipeds) for thirty years. A zoology professor at the University of Guelph from 1973 to 1996—and author of more than one hundred publications on marine mammal biology and conservation—he has been the science advisor to the International Fund for Animal Welfare (IFAW) since 1999. He is a long-standing member of the Seal Specialist Group of the International Union for Conservation of Nature and Natural Resources (IUCN).

Prior to joining the IFAW, Dr. Lavigne served as executive director of the International Marine Mammal Association, an international non-governmental organization concerned with the conservation of marine mammals worldwide.

Today, his major interests are conservation biology, natural resources policy, and the pursuit of ecological sustainability.
Uko Zylstra (Calvin College, Grand Rapids, MI): A couple of the speakers made mention of the fact that we need to reduce the human population—I do agree with that—but I want to raise a point that was not mentioned. In the 1970s, George Borstrom, then at Michigan State University, analyzed human population equivalents with regard to animals. And the animal to human population equivalence, as I recall, was about 14 to 15 billion. That’s a pretty large number of human population equivalents. Why isn’t that in your analysis and your attempt to deal with some of the problems with regard to ecological footprints? Animals have large ecological footprints. It’s not in the equation that I saw this morning. Any explanation? And to what extent should we incorporate that? In other words, Borstrom dealt with domestic, not wild, animals, and that’s a pretty large impact. How does that relate to our own dietary system, etc., our whole food system?

William Rees: A couple of points: obviously animals do have a large footprint, but in our analysis, for example, much of it is attributable to the human footprint because domestic animals are simply a way-station for energy and material flows from the ecosystem into humans. That massive population of animals is a supportive network for the human system. There is no question that if we eliminate the animals we could sustain a larger population of humans. Something like half the grain grown in North America is fed to animals. If we moved toward a more vegetable- and fruit-based diet and eliminated the animal intermediaries you could sustain a larger human population. But it doesn’t get at the fundamental problem, which is the constant pushing upward of human population numbers. And as wealth increases, the quantity of animals and animal protein in our diet increases.
pace. It goes right back to some of the things that Dave said. People want those higher dietary standards. China is becoming a huge meat-eating country. If you simply extrapolate—one of their specific objectives is to attain the same levels of meat consumption as the West—you’d have to have the entire planet covered in grazing lands just to sustain that demand of the Chinese. So there is inherent conflict here and I think you are right in pointing out that these animals in fact have a huge footprint; but it’s really part of the human footprint.

Klaus Ammann: A study was done in the 1970s by an interdisciplinary group at the University of Stuttgart and Berkeley on how much space does humanity need, if it could be organized in an ideal way with agriculture, with vacation space, with everything involved. Their result was the size of the island of Taiwan. So I don’t want to comment further on that but I would just like to say there is some hope still. With respect to our behavior and our organization we can do much better and the potential is gigantic.

David Lavigne: One reason why it wasn’t in my talk was largely the time constraint, but I think you’ve probably seen a paper by Palmer, who calculated the agricultural footprint of the United States, and the largest component of that was beef. And I think he recommended that the United States could reduce its agricultural footprint by consuming far less beef than currently. And the other reason I left it out was I assumed most people here would be from the plant biotech field so I didn’t want to take a shot at beef.

Rees: If I may just add something: you could contain the whole of humanity on a place like Taiwan but if you put it in the context of the second law of thermodynamics about half of the rest of the planet would be directed towards sustaining the consumptive activities going on in that little space. You can read all kinds of crazy notions about the whole of the human population, if condensed, would occupy less than a cubic kilometer. It’s irrelevant when you’d need the productive capacity of half of the rest of the planet to sustain the consumptive activities of that relatively small mass of humans.

Ammann: You don’t even know the study and you ridicule it. They did the study by using all the parameters including food production and were baffled themselves that it was this size, not more. Not a few cubic meters—about the size of the island of Taiwan. Let’s think about this. It should not be dismissed out of hand.