Four Fallacies in Agricultural Sustainability,

and Why They Matter:

Part 4- Technology Will Solve All Problems

GEORGE MORRIS CENTRE

MAKE INFORMED DECISIONS

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Introduction

The view that additional steps should be taken to confirm that food is produced sustainably has become ubiquitous in Canada, as well as in other developed countries. Consistent with this, the downstream food industry has become much more interested in the upstream elements of its supply chain, especially the farm segments and the technologies/processes it employs, and has sought to derive metrics that measure and influence the sustainability of this food end product. This plays out across a range of parameters, including carbon footprint, water use, pesticides, fertilizers, antibiotics, hormones and growth promotants, animal welfare, labour standards, as well as others. In some cases, specific technologies or techniques related to the above have been targeted, such as genetically modified, specific pesticides, specific animal health products, certain livestock housing systems, etc.

This represents a plausible response to increased public awareness of natural resource scarcity and of food security. However, important aspects of this movement are simplistic, misguided, or simply wrongheaded, and following these through to their logical extent presents the prospect of pitfalls for the agri-food system. Perhaps more fundamentally, it begs the question as to how the agri-food system, and primary agriculture in particular, grew to become so unsustainable to begin with. In Canada many generations of farmers have seen themselves as stewards of the land, farm product production has greatly increased and intensified, and rather than starve or cause mass illness, we have produced significant surpluses for export at steady or improving quality standards.

Others, including some farmers, are deeply concerned about the future of the agri-food system, how natural resources, human resources, and technologies are used and what the potential consequences may be. There are examples that can be cited that lend support to these types of concerns.

This highlights a gap that has emerged in our understanding of how agri-food production systems develop and evolve, and how this relates to sustainability. The purpose of this paper is to help develop the case for a more holistic and coherent view of agri-food sustainability as a process. As a means of advancing, four fallacies related to agri-food sustainability are identified and discussed in the sections below. These are:

1. We should tread more lightly on the agricultural land base
2. Small farms are better
3. Farm technologies can be picked from a menu
4. New technology will solve all problems

This paper, which is the fourth and final paper in the series of four, considers the final fallacy- that new technology will solve all problems.

New Technology Will Solve All Problems

Agriculture, perhaps more than any other industry, has been shaped by technology and changes in technology. This ranges from the earliest of innovations in farm machinery, such as the seed drill or the self-scouring moldboard plow, to techniques such as the crop rotation and three-field system, and to innovations in chemistry and microbiology that provided livestock medications, vaccines, pesticide products, food preservatives and food packaging products. These innovations in technology are a response to the ever-changing pressures of biology, a changing climate, and shifting markets. Meeting the challenge of innovation in technology is an important focus of effort in our colleges of agriculture and the federal and provincial agricultural research stations. There is also extensive investment and effort by the private sector as well as by agri-food organizations. The situation is similar throughout the western world, and many in the agri-food sector take pride in what has been accomplished. Our ability to support an ever-increasing global population at a higher standard of living, with fewer people engaged in food production and professional farmers that can enjoy middle class lifestyles are all products of this innovation.

Yet some, perhaps an increasing number, take a very different view of technology in agriculture, especially the broad sphere referred to as “biotech”. For this group, intensification and new agricultural technologies are broadly seen as failures in the making, almost from their introduction. First, new agricultural technologies are seen as “messing with mother nature” in a very intimate way, which creates risks which we may not perceive until it is too late. Second, technologies are seen in this view as failing on a regular basis. For example, pests become resistant to technologies designed to treat them, or collateral damage and other unintended consequences occur from their use. Alternatively, technologies are seen as accelerating the process of moving from a more pastoral rural society to one of fewer, larger farms. Some of these ideas have contributed to a categorical rejection of a broad suite of agricultural technologies.

There is an emerging science, based in ecology, that can be drawn upon to highlight the uncertainty into which agricultural technologies are developed and used. It emphasizes that nature and biology is populated with unknown relationships and uncertain carrying capacities; these can shift biological equilibriums on a sudden or episodic basis, rather than gradually. These can occur due to factors such variations in weather patterns, incidents of severe weather, geologic events, human disease pandemics, and human intervention in biological systems, such as occurs in agriculture.

This presents a very different perspective than one in which agricultural technology is designed to build upon and augment what is essentially a known and stable system. The dichotomy between these two approaches- one emphasizing that biological systems can become unstable and suddenly flip to a different state, the other focusing on stability around an equilibrium state (Holling, 1996) need to be better understood and appreciated in agriculture. By default, we have grown into the assumption of a stable equilibrium that we build upon with technology in agriculture.

This recognition should not lead to the categorical rejection of new agricultural technologies, however. Rather, it should lead to a better respect for the adaptation and complexity of biological systems, and the critical need for an ongoing process of careful technological development, as individual technologies are challenged by the complexities of biology and climate and must be replaced by new technologies to sustain food demands, and to protect the resilience of the agricultural system. Indeed, the new agricultural technologies that will be needed in the future to deal with pests and conditions we can only speculate about now will be shaped by the experience of new technologies introduced today. This experience will include how agricultural technologies are used, fail, and how patterns of use and management can be influenced to constantly improve the effectiveness, safety, and longevity of specific technologies.

As discussed below, technology innovation, adoption, use management, and failures or unintended effects are part of a cyclical process. Most agricultural technologies do not last forever due to the complexity and vagaries of biology and the natural world. The best hedge against failures and negative side effects is to be constantly developing next generation technologies in anticipation of future limitations in existing technology.

In this regard, the mainstream agricultural community needs to acknowledge that failures and unintended consequences can and do occur with agricultural technologies, as emphasized by the sustainable agriculture movement. The sustainable agriculture movement must acknowledge that the solution to technological failures it highlights is not to restrict new technologies, but rather to accelerate the development of new, improved technologies (for precisely this reason). Food marketers should appreciate the importance of technological development in agriculture, and understand how food marketing initiatives that restrict agricultural technologies inhibit this process.

Uncertainty in Agricultural Systems

Agricultural technologies confront an inherently complex biological system fraught with uncertainty regarding ultimate effects. A framework within which to understand this is developing in the growing literature on ecological resilience. *Resilience* has been defined by Walker and Salt as "*the capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks*. Maintaining system resilience is a key element of sustainability (Rees, 2010); others suggest that resilience should simply replace sustainability as a more meaningful concept or goal (Benson and Craig, 2014).

Holling (1996) identifies properties of ecosystems, which can be extended to agricultural systems:

- Ecological change is not linear; it is slow and episodic, with slow accumulation of natural capital punctuated by sudden change due to natural events or man-imposed disturbances
- Ecological systems vary spatially, and scale and its ranges matter
- Ecosystems do not have a single equilibrium with functions controlled to remain near it
- Management that applies fixed rules in ignorance of the above lead to systems that lose resilience and gradually break down in the face of disturbances that could previously be absorbed.

Thus, resilience focuses on the inherent complexity and adaptation of ecological systems. To illustrate, one of the examples documented of the complexity of biological systems experienced is the following, reprinted from Holling (1996):

> *Under natural conditions in east and south Africa, the grasslands were periodically pulsed by episodes of intense grazing by various species of large herbivores. Directly as a result, a dynamic balance was maintained by two groups of grasses. One group contains species able to withstand grazing pressure and drought because of their deep roots. The other contains species that are more efficient in turning the sun's energy into plant material, are more attractive to graziers, but are more susceptible to drought because of the concentration of biomass above ground in photosynthetically active foliage.*
>
> *The latter, productive but drought-sensitive grasses, have a competitive edge between bouts of grazing so long as drought does not occur. But, because of pressure from pulses of intense grazing, that competitive edge for a time shifts to the drought-resistant group of species. As a result of these shifts in competitive advantage, a diversity of grass species serves a set of interrelated functions- productivity on one hand and drought protection on the other.*
>
> *When such grasslands are converted to cattle ranching, however, the cattle have been typically stocked at a sustained, moderate level, so that grazing shifts from the natural pattern of intense pulses separated by periods of recovery, to a more modest but persistent impact. Natural variability is replaced by constancy of production. The result is that, in the absence of intense grazing, the productive but drought-sensitive species consistently have the advantage over the drought-resistant species and the soil- and water-holding capacity they protect. The land becomes more productive in the short term, but the species assemblage narrows to emphasize one functional type. Droughts can no longer be sustained and the system can suddenly flip to become dominated and controlled by woody shrubs. That is, ecological resilience is reduced.*

Similar complexity and adaptability must exist in agricultural systems. For example, European tillage technology was initially employed by settlers in the development of western Canadian agriculture. However, these practices ultimately led to the need for summerfallow practices which left soils vulnerable to wind erosion in droughts. When confronted in the 1930's by severe multi-year drought, soil conditions changed drastically, in some cases permanently (more on this below).

The 2010 report of the US National Academies of Science committee on agricultural systems highlighted the inherent complexity of agricultural systems and on system resilience. The NAS committee extended the system complexity to the conceptual complexity, citing Batie, (2008):

> *Sometimes built capital, such as machinery or chemicals, can substitute for natural capital, such as natural soil fertility. Food productivity has risen over time in the United States, in part, because of the substitution of fertilizers for natural soil fertility. If the substitution is viewed as socially acceptable, if fertilizer is affordable and effective, and if its use is not accompanied by unwanted or detrimental side effects, then the loss of natural soil fertility as a result of a farming practice might be viewed as sustainable. If, however, fertilizer is viewed as a poor substitute for natural fertility, as having important unwanted side effects, or is thought to be unaffordable or ineffective in the future, then a farming system that results in losses of natural fertility of the soil will be viewed as unsustainable* (Batie, 2008).

Thus, the complexity of biological systems, as well as human perceptions of it, challenges agricultural management. In this environment, there is a justified concern new technologies could make production systems more vulnerable to certain perils, even as overall productivity of the system appears to improve. This deserves attention and caution.

However, it is critical to recognize that intervening in natural and biological systems with management and technology is precisely what agriculture is, and it is something we have been doing since the ancient Mesopotamians began farming 10,000 years ago. As a result, we are forced to wrestle with the complexity and uncertainty described above, and to capitalize on our mistakes and misadventures and learn to manage both productivity and vulnerability. We can hardly step out of this process now, as we strive to produce more to satisfy demand and reduce hunger. Rather, recognizing the inherent complexity of biological systems and the need to retain resilience should be a check on our hubris, highlight cautions, challenge us to ever higher standards, and condition our expectations for agricultural technology as we press forward with it.

Understanding Agricultural Technology as Cyclical Process, Mitigated by Innovation

Many agricultural technologies are characterized by a loosely predictable cycle. They are developed and then adopted. As adoption and technology use increases, the biological system in which farming operates begins to adjust. This eventually (sometimes suddenly) leads to side effects and failures in technology, real or perceived, which in turn leads to dis-adoption of the technology, either voluntary through the market process or as products are withdrawn by technology providers and/or government regulators.

Some would view this as evidence that we can’t really mess with mother nature. But if we understand that specific interventions in biological systems in agriculture are only temporary, then particular agricultural technologies reaching obsolescence should be expected as the biological system reorients itself. Moreover, our perceptions and expectations of technologies change over time; just as we have higher standards today for air transportation, childrens' car seats, and pharmaceutical packaging than we did in the early 1970's, so too we have higher standards today for things like farm equipment safety, fertilizers, and veterinary drugs. Out of respect for the complexity and power of biology and nature, as well as increasing public standards for technology, we must be constantly prepared to adjust ourselves with new technologies and techniques.

We need to anticipate and be prepared to participate in this agricultural technology cycle. Doing so creates benefits in terms of technical knowledge spillovers, and knowledge spillovers that relate to management and use of technology. But perhaps the most important point is that we must be constantly innovating new agricultural technologies, because we should anticipate that those currently in use will eventually fail in some respect, and that a lack of new technological solutions available if/when that occurs could be catastrophic. Thus, the real cost of categorical rejection of agricultural technologies is that it would bring the process of innovation, and the competitive market in the provision of technology with its associated investment, to a virtual halt. The importance of this innovation *process* seems to have been missed by many.

Some examples help clarify this.

Atrazine

Atrazine is a triazine herbicide used against broadleaf weeds and grasses. Certain crops (notably corn) are tolerant to atrazine. It has a soil residual that allows weed control over a prolonged time period, generally exceeding a single growing season. It offers a range of alternatives for application- pre-plant, pre-emergence, and post-emergence.

In Canada, atrazine came into use in the early 1960's. Its application is focused primarily on corn. Prior to the introduction of atrazine, the predominant method of weed control in corn was through row cultivation, which could not remove the weeds growing within the row and was time consuming. Other herbicides that were available for corn were either ineffective for the same broad spectrum of weeds, or could damage the crop. Thus atrazine was viewed as something of a miracle product, and its increase in use was consistent with an expansion in corn acreage, partially due to increases in yield from greatly improved weed control (as well as improved corn genetics, and other factors) and from a desire to plant corn to take advantage of the weed control benefits of atrazine that could extend multi-year.

The ubiquitous use of atrazine as a corn herbicide by the 1970's and 1980's eventually led to side effects. Triazine resistant weeds developed. Residual atrazine was observed as a problem of emissions into groundwater (see for example Fleming, 1992, Goss *et al* 1998, and Novakowski *et al*, 2006). Atrazine residuals in the soil reduced cropping flexibility as farmers became locked into growing corn due to the soil residual. There are ongoing discussions regarding potential adverse effects on frogs due to atrazine exposure, but these remain the subject of scientific debate. As these side effects occurred, and new herbicides that avoided some of these problems were developed, atrazine use declined in the late 1990's and 2000's in favour of other herbicides.

Aspects of the experience with atrazine are depicted in Figures 1 to 3. As atrazine became more widely and heavily used, weed resistance increased (Figure 1); this has also occurred with later generations of herbicides that followed atrazine, such as imazethrapyr, and more recently, glyphosate. Figure 2 illustrates the emission issues with atrazine as of the early 1990's. Reported atrazine use in Ontario has been in decline in Ontario since the 1980's, initially succeeded by other herbicides such as metalochlor and now, glyphosate (Figure 3).

What benefits resulted from the development and use of atrazine? Its use contributed to increased corn acreage and yields, and it created important knowledge. Its development and roll out created technical knowledge in pesticide chemistry that surely benefited the development of successor herbicides. We also learned important lessons about weed resistance, and that as a single herbicide became ubiquitous and heavily used, unintended consequences could occur. This awareness has been part of more recent crop protection technology rollouts- Bt corn and the management of resistance through refuge corn acreage serves as a current example. Ultimately, because the search for successor herbicides to atrazine occurred even as its use was expanding, when difficulties mounted with atrazine alternatives were available and the problem of herbicide resistant weeds was overcome. At least temporarily.

Tillage Systems in Western Canada

European settlers arriving in western Canada in the 19th and early 20th centuries brought their farming techniques and tillage tools with them. The natural fertility of prairie soils, which proved more than adequate for crop production using these techniques between the 1800's to 1920's, eventually began to decline and summerfallow developed as a means of conserving soil moisture and soil nitrogen. However, the fallowed land which was subject to regular tillage for weed control purposes left soils particularly vulnerable to wind erosion and soil drifting during the severe drought conditions experienced in the early 1930's. Some of the worst affected land was abandoned (Brandt, 2010). McKonkey notes that "Major soil drifting was observed in the 1917 to 1920 period over much of the Prairies…The need to retain crop residues on the soil surface to control soil drifting was obvious during the dust bowl years of the 1930s". (McKonkey, 2010).

The tillage tools in use at the time of the droughts in the early 1930's were largely plough and disc implements that mixed surface residues into the tilled layer of soil. As it became evident that these tillage technologies had contributed to the dust bowl, it stimulated the search for alternative tillage technologies. By the mid-1950's these earlier tillage technologies were being replaced by sub-surface tillage implements that left residue on the soil surface and could sever the roots of weeds; however this still left fallow acreage at risk from wind erosion, due to the frequency of tillage and soil disturbance. Attempts were made to address this through reduced tillage and weed control by herbicides, especially in the 1970's. However these proved much more costly than tillage and created a range of new problems, such as cooler soil temperatures and mineralization of soil nitrogen (Brandt 2010).

Direct seeding, or no-till, technologies were being adopted starting in the late 1980's. Under direct seeding systems, no tillage occurs before planting, and only a subset of the area seeded is actually disturbed to form a furrow for the seed, allowing stubble to remain for cover and to trap moisture. It has reduced the need for fallow acreage using either mechanical tillage or herbicides. As such it has allowed for continuous cultivation of land that previously had to be fallowed, reduced soil erosion associated with mechanical fallowing, and reduced the need for chemical weed control on fallow acreage. It also decreases fuel consumption, and increases soil organic matter retained (Alberta Agriculture and Rural Development, 2009). Adoption rates have increased rapidly, as evident in Figure 4 below; no-till adoption rates in Alberta increased from less than 5% in 1991 to well over 60% in 2011. Evidence of significant reduction in sediment from runoff water has been observed from no-till fields compared with conventionally tilled fields, as well as increased biodiversity through increased arthropods and, in some cases, bird populations (Wicklum and Gray, 2010).

As direct seeding systems have been adopted, in effect it has allowed significant increases in arable acreage to be accessed, without conversion of pristine land into agricultural use. This has occurred as summerfallow acreage has declined. This is illustrated in Figure 5. Since the early 1980's, summerfallow acreage in western Canada has declined steadily. Based on recent years, the decrease in summerfallow, which amounts to an increase in acreage that can be cropped, is about 20 million acres compared with the early 1980's.

Thus, in important ways tillage practices used in Europe and eastern North America failed in western Canada in the early twentieth century. When employed in the context of western Canada, these tillage practices had the effect of depleting the natural soil fertility of prairie soils, and through the development of fallowing left soils especially vulnerable to drought. The bitter experience of the dustbowl and loss of productive soils in western Canada provided the impetus for technological solutions, which took decades to develop. As development of new tillage/planting systems developed, the multi-year droughts of the magnitude of the early 1930's did not occur. However, the multi-year drought of the early 2000's was at least as severe. According to the Drought Research Initiative, the drought of the early 2000's was the most severe in over 100 years[1]. Even though it was worse, this drought did not result in the same effects in terms of long-term losses in soil and fertility as the dustbowl. Lawford (2011) observed:

> *While drought generally does not damage infrastructure, it can lead to irreversible effects when farming operations are abandoned, livestock herds and land are sold, and families move to other areas. While stories from the 1930s about such irreversible impacts are common, they appear to*

[1] http://www.drinetwork.ca/impacts.php

> *have been less common during the 1999-2005 drought even though precipitation anomalies of similar or even greater severity persisted in some regions.*

The development and adoption of direct seeding technology contributed to this.

Intestinal Parasite Controls in Poultry

Poultry are subject to infection by intestinal parasites that have significant negative impacts of their growth and health. The development of a modern commercial poultry industry has been shaped in part by the challenge of these diseases. In a review of intestinal parasites in poultry, McDougald (1998) notes that all species of *coccidia* (parasites that cause coccidiosis) are ultimately pathogenic to chickens and turkeys with varying virulence. Mortality rates due to *histomonas* (blackhead) infections in turkey are observed at up to 90% (McDougald, 1998). Thus, the search for effective means of intestinal parasite control has been an important and ongoing effort in poultry.

Research on intestinal parasites in poultry accelerated after the Second World War. One of the significant chemical products launched at this time was the sulphur-based feed additive sulphaquinoxaline in 1948, and many others followed (De Gussem, 2007). This included the "arsenical" group of medicated feed additives, such as roxarsone as both growth promotant and anti-coccidial, and nitarsone, a preventative treatment for blackhead in turkey. The use of these products allowed the poultry industry to grow and expand more quickly (De Gussem, 2007). This is illustrated in Figure 6 below for anti-coccidial treatments, from Reid (1990). US broiler production literally tripled between 1950 and 1970; this was coincident with a proliferation in available chemical treatments as medicated feed additives. It also allowed for a decrease in the consumer cost of poultry; Campbell (2008), notes that "Following the commercial introduction of sulphaquinoxaline in 1948, the price of broiler chickens in the United States declined sharply, and continued to decline over many years, during which sulphaquinoxaline was succeeded by other coccidiostats" (Figure 7).

However, one of the difficulties with chemical feed additives to combat intestinal parasites is resistance. As a result, many of the chemical feed additive products introduced in the 1950, 60's and 70's were ultimately failures, and many were withdrawn or declined in use due to resistance problems (Reid, 1990, De Gussem, 2007). As chemical feed additives were confronted with pest resistance and declined, these were replaced by a new category of control products- ionophores. The first ionophores were introduced in the early 1970's (De Gussem, 2007); this is identified as monensin in Figure 6. The period following the early 1970's shown in Figure 6 is one in which broiler production again increased very rapidly. There are probably a number reasons for this, including rapid increases in chicken demand, but it is consistent with the increased availability of ionophore anti-coccidials that are less prone to resistance than chemical additives (De Gussem, 2007). Today, ionophores are facing pressure as part of a broader concern regarding antibiotic use in livestock production, which in turn drives the demand for ongoing solutions for intestinal parasites in poultry.

The above highlights the following. Because intestinal parasites were such a prevalent problem in poultry production, significant increases in production are attributed to the development of technology for control. Thus there were tremendous benefits associated with these products; it may not be a stretch to suggest that it would have been difficult to have the meaningful commercial poultry industries we have today absent these technologies. As many of these technologies failed, it highlighted the problem of pest resistance and its management. This resulted in the withdrawal of many control products, and a focus on management of resistance through "shuttle" programs in which treatments were introduced only in specific stages of production and then withdrawn, or intentionally switching of treatments on a regular or periodic basis. Importantly, the ionophore products were in development and became available to the market as the difficulties encountered with chemical feed additives came to bear.

Public perception of additives in poultry feeds has also been an issue. For example, Roy *et al* (2013) cite a reference that states "Among the general public, the word "arsenic" has become almost synonymous with the word "poison". This view is consistent with the withdrawal of arsenical feed additive products used in poultry such as roxarsone[2] in 2011. Ionophores are also under pressure. One way to view this is that, just as standards and public expectations for other, non-food related products have increased over time, so are the standards for farm and food technologies. This demands constant innovation in technologies so that these ever-increasing expectations can be exceeded.

Conclusions

It is critical to recognize that the biological world in which agriculture operates is not static. It is constantly adjusting to past human influences, invasions of foreign organisms, and weather extremes. Agriculture also operates in a situation in which much of the decision making relative to this biological world is delegated to individuals as farmers, operating in a market context. These markets also are not static. Technologies that influence agriculture are developed by private companies, also operating in a competitive market context, under some regulatory control by governments. The public to greater or lesser degrees has awareness and develops perceptions regarding this environment and technology use within it.

With this more fulsome recognition of biological uncertainties, decentralized decision making, and ranging public perceptions, it should come as no surprise that agricultural technologies fail in some respects. A respect for the power and dynamics of the biological world in which farming occurs highlighted in the resilience literature should lead us to expect this. Resilience also reminds us that our challenge in increasing production to feed a hungry world is not one in

[2] http://www.theglobeandmail.com/life/health-and-fitness/sales-halted-after-arsenic-found-in-chicken-drug/article591962/

which we are building upon a fixed base; it is a shifting base replete with biological inter-relationships that we do not fully understand. To some degree, we are at imminent risk that this production base could shift, perhaps suddenly and irreversibly, into a state in which past expectations of food production can no longer be met, let alone augmented.

This situation demands constant innovation and willingness to adopt new technologies, rather than an abundance of caution curtailing it. One of the lessons of resilience, as embodied in the illustration of the dust bowl of the 1930's in western Canada, is that the existing agricultural technology set can suddenly and decisively prove inadequate and permanently change the production system. This did not happen with atrazine or intestinal parasite products in poultry, as there was a willingness to experiment with new technologies and public and private investment in these occurred prior to critical, permanent negative changes.

If we were unwilling to take on the risk of new technologies, instead we implicitly take on the risk that staying the course with existing technology will continue to "work" indefinitely. This lies at variance with the reality of growing populations and new middle classes with growing demands for food, and the market orientation of farming and agricultural technologies. It also lies at variance with past experience with agricultural technology and adaptation in biological systems and climate.

The mainstream dialogue on agricultural sustainability must be deepened to acknowledge and better discuss these issues. As identified in the previous papers in this series, there is a growing trend of categorical rejection of certain agricultural technologies, in particular motivated by food marketers. The discussion in this paper, and the previous three papers, suggests that this is a very dangerous trend.

The first casualty may be the market access of farmers employing approved and validated technologies; this lies in conflict with a past in which farmers have been treated as citizens with particular rights regarding market access for their products by elements of agricultural policy. The second casualty is likely to be investment in research and innovation to develop new technologies. Apart from the obvious economic losses, this trend would leave us exposed as technologies currently in use fail or become inadequate, with investments to develop the next generation of technologies lacking. A third casualty would be the long-run impairment of productive capacity that can be anticipated over time as we step away from the technology process described above. When hunger still exists to a large extent in the world, there is a sense of moral obligation, as well as economic opportunity, to use resources to improve the lives of those most needy. Moreover, we cannot take the production base we have for granted, as it can shift suddenly, and existing technologies may prove inadequate to mitigate.

Finally, there is no implied contrast necessary here between "industrial" agriculture and "local" agriculture. A subset of the population in rich countries is interested in having direct relationships in purchasing their food with farmers that choose not to use particular agricultural technologies. The free-enterprise, market oriented system in which agriculture operates in Canada is sufficiently flexible to accommodate this, with ever increasing diversity of markets and products. It is only as major food marketers responsible for purchasing the preponderance of farm products step in with private standards that restrict technologies, or influence governments to this end, that the concerns identified here result.

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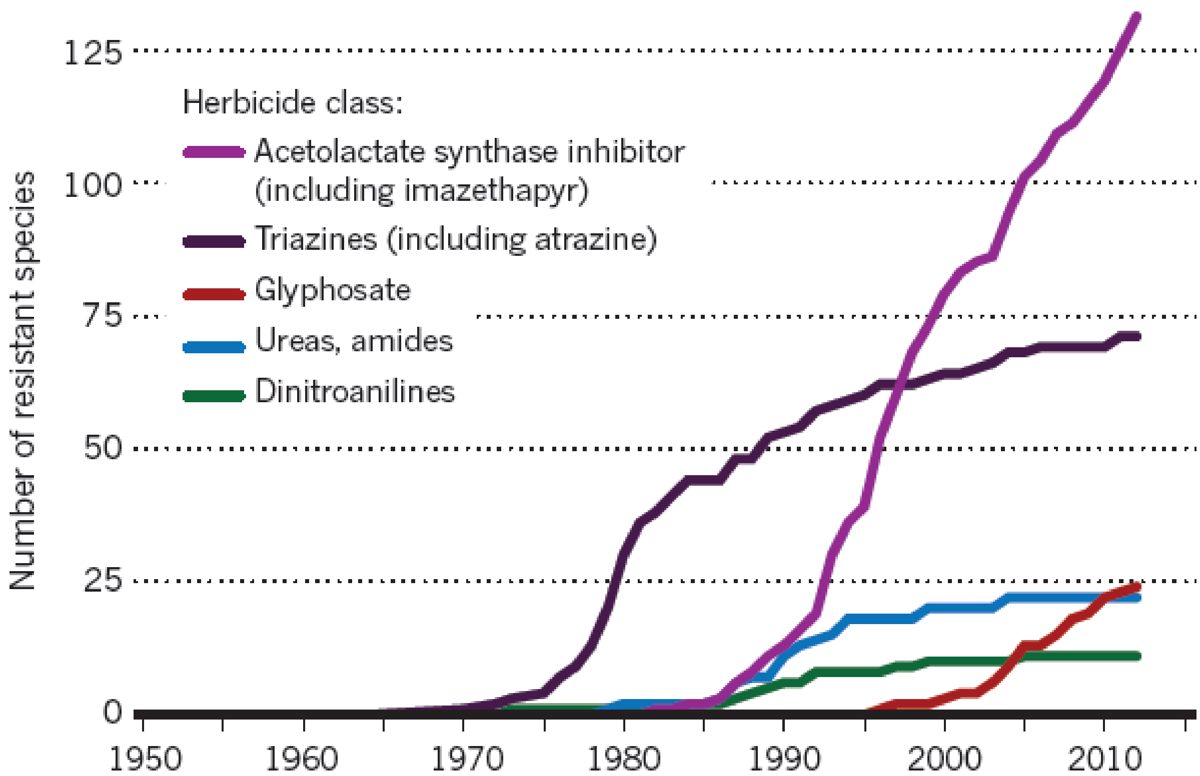
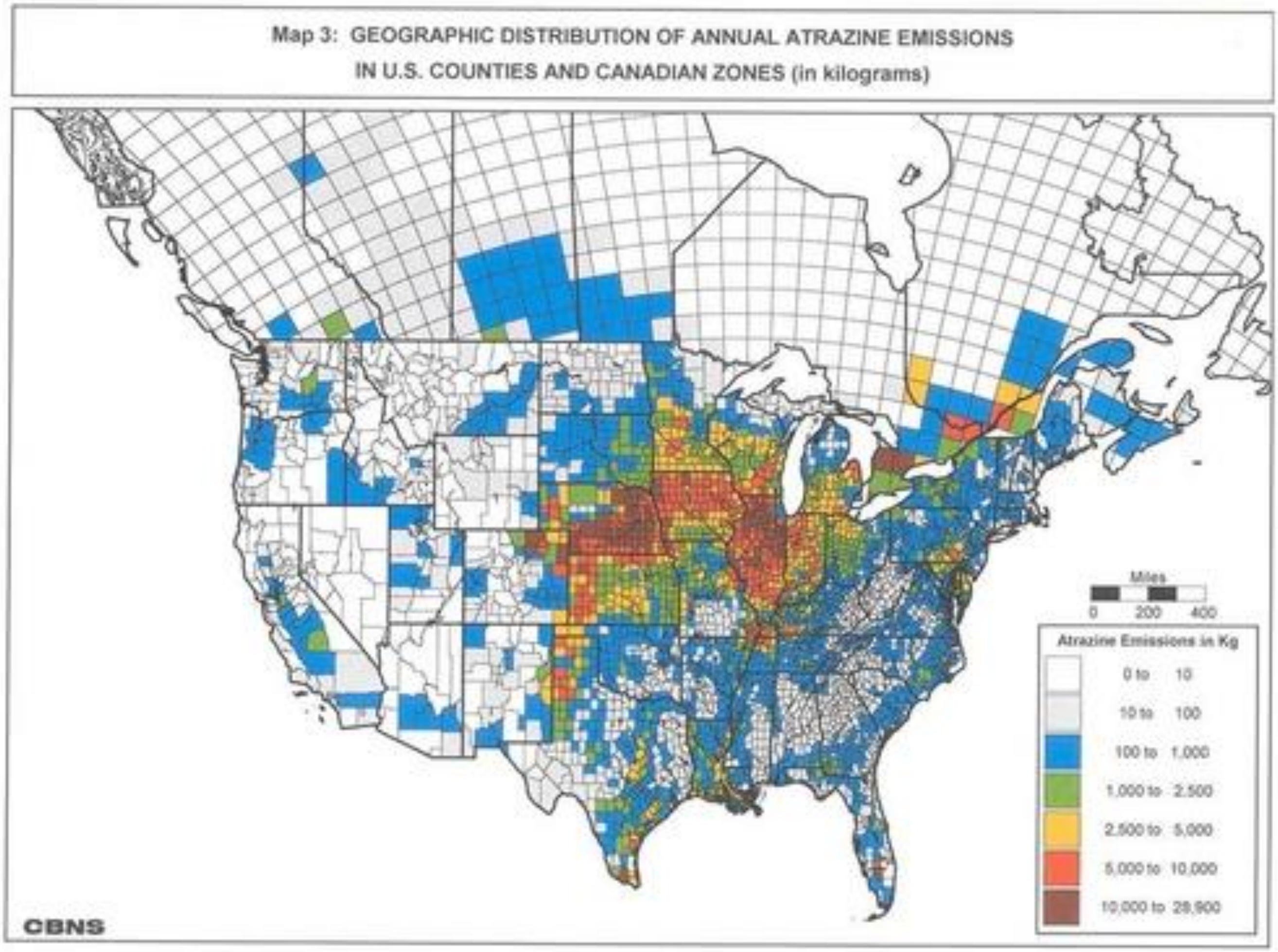
Figure 1 Development of Weed Resistance to Herbicides



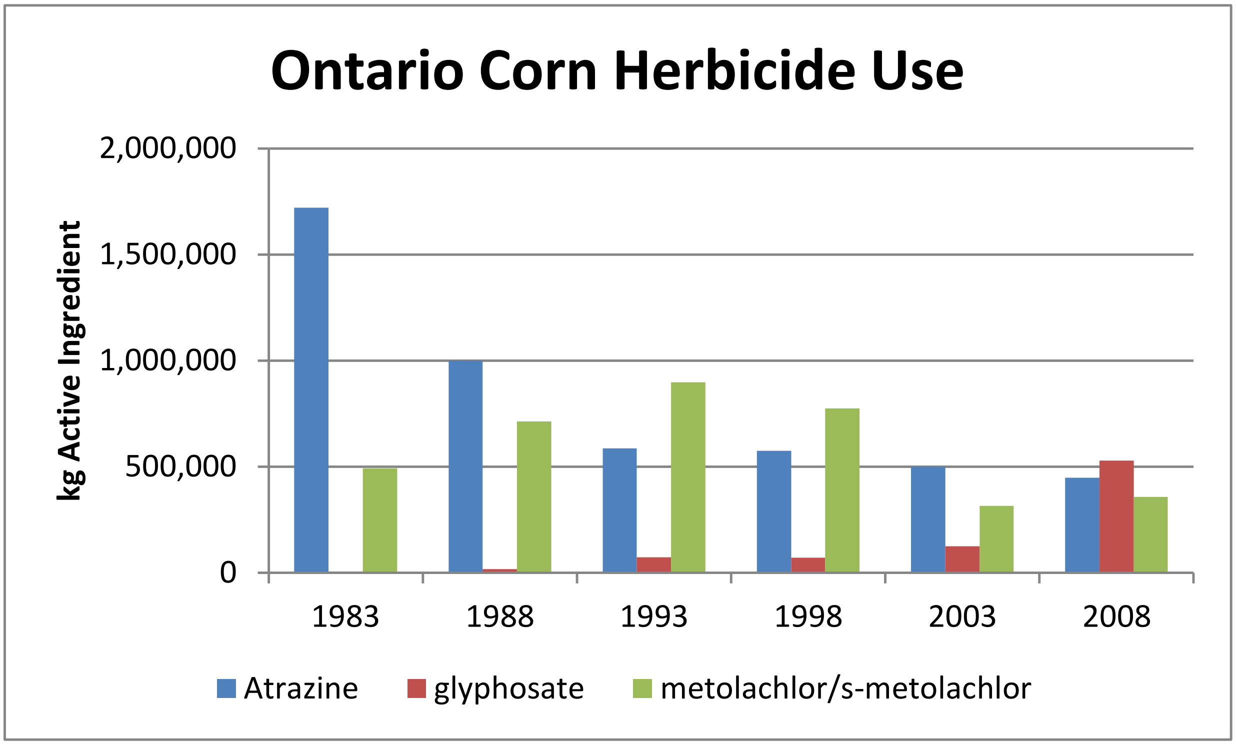
SOURCE: IAN HEAP, INTERNATIONAL SURVEY OF HERBICIDE RESISTANT WEEDS WWW.WEEDSCIENCE.ORG/GRAPHS/SOAGRAPH.ASPX (2013).

Figure 2 Incidence of Atrazine Water Contamination



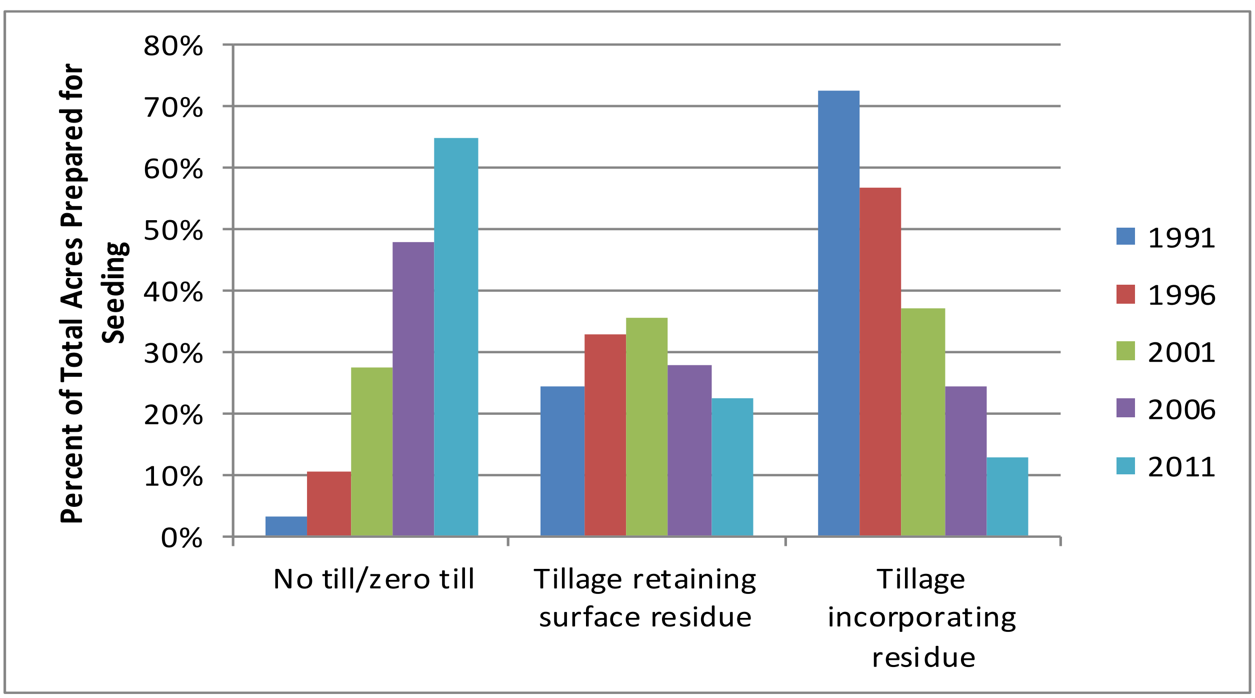
Source: NOAA-ARL 1991 data

Figure 3 Ontario Corn Herbicide Use



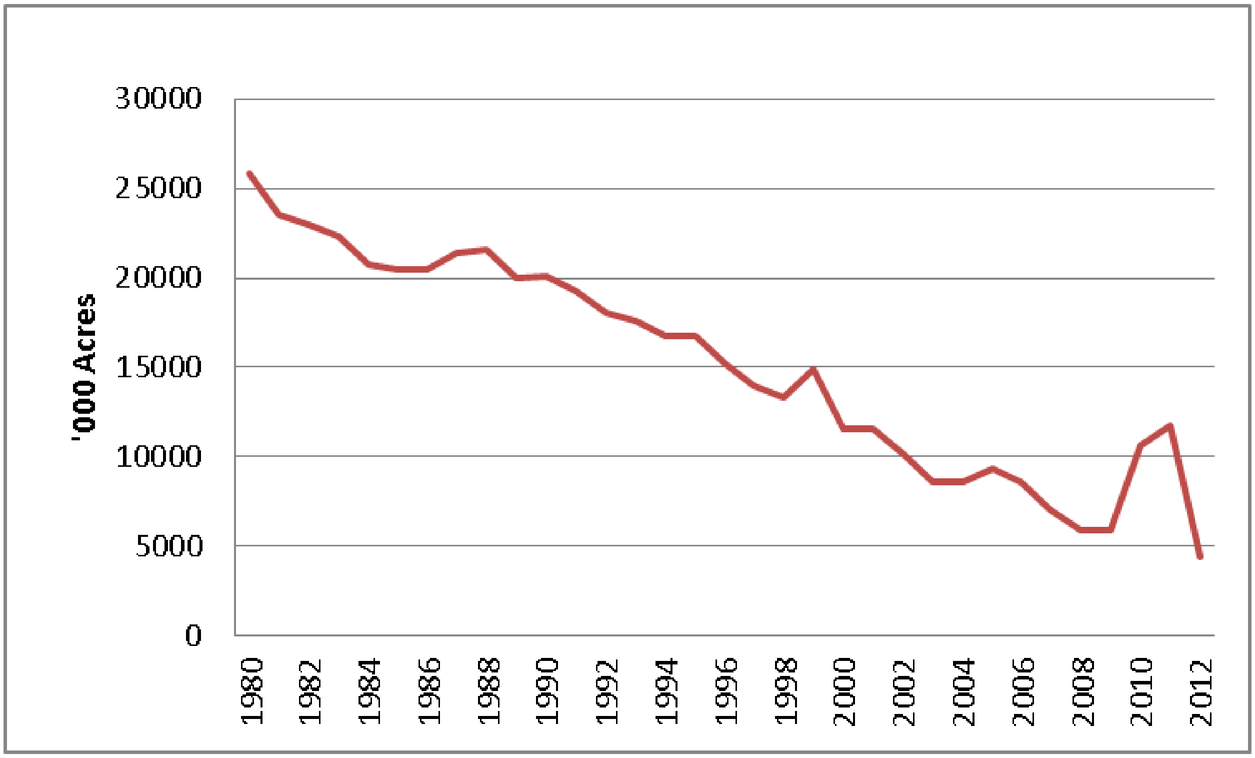
Source: Ontario Pesticide Survey

Figure 4 Proportion of Alberta Acreage Seeded by Tillage Method



Source: Statistics Canada, Census of Agriculture

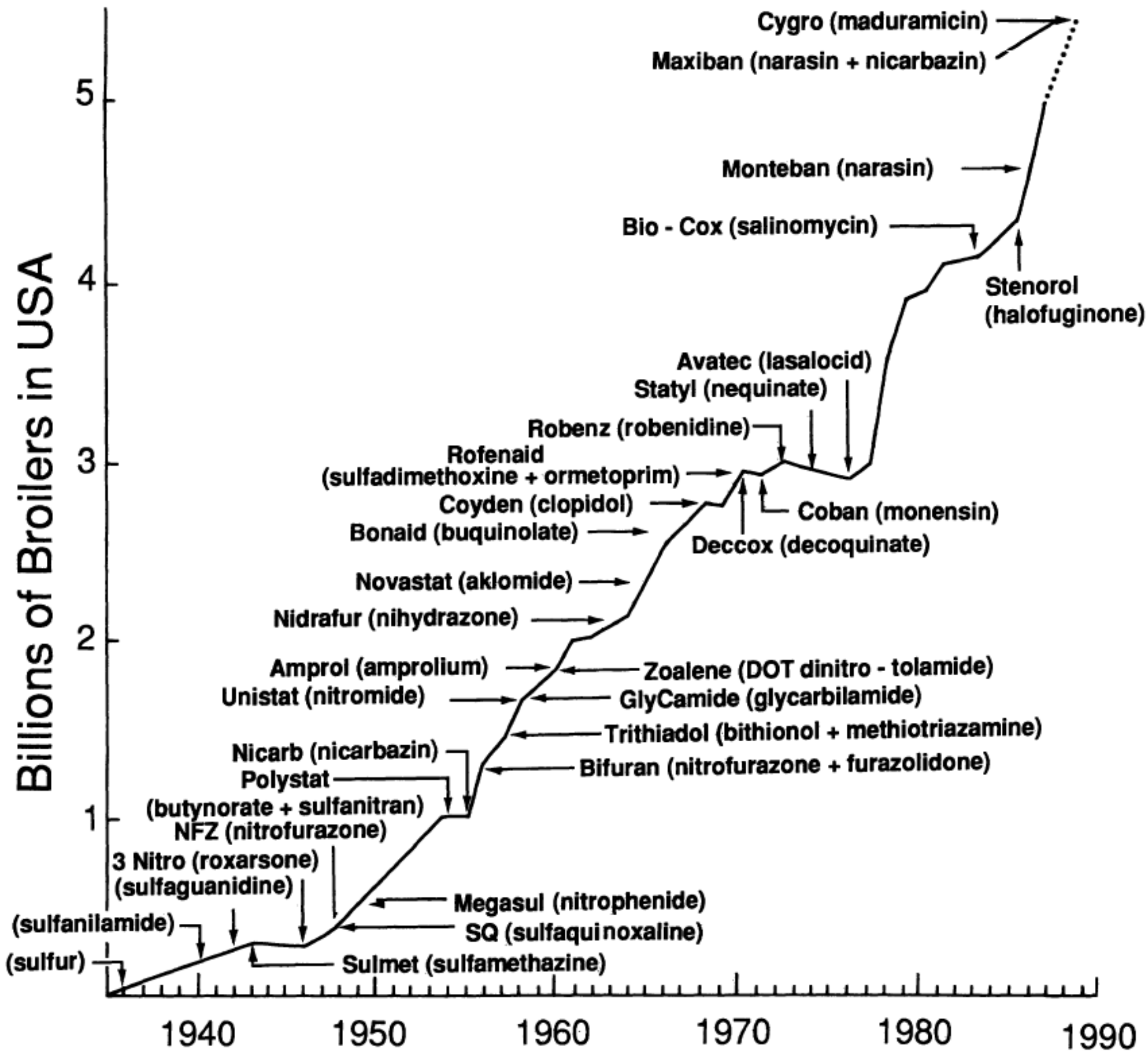
Figure 5 Summer-fallow Acreage in Western Canada



Source: Statistics Canada

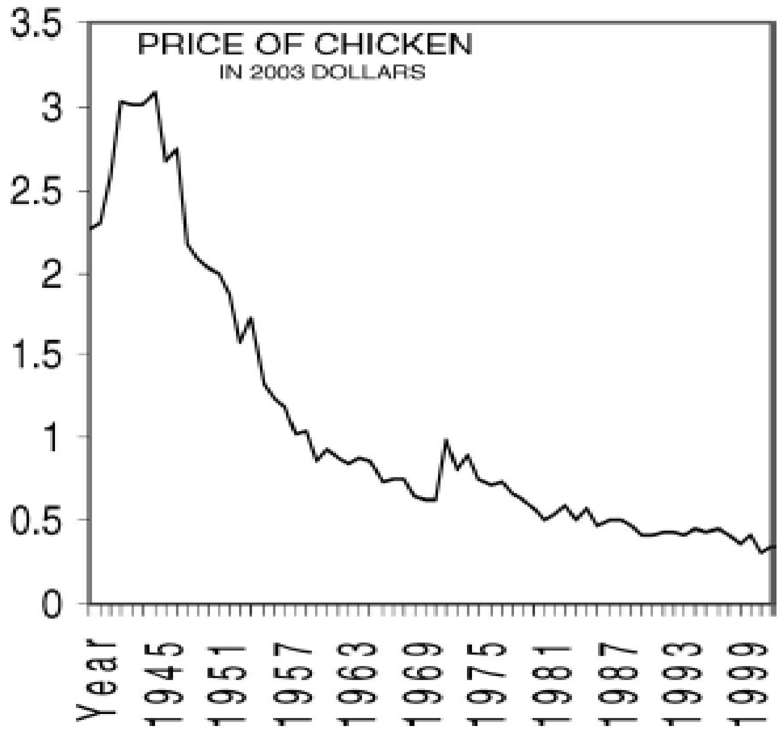
Figure 6 Anticoccidial Products Introduced in the US vs.

US Broiler Chicken Production 1930-1990



Source: Reprinted from Reid, 1990

Figure 7 US Chicken Prices



Source: Reprinted from Campbell, 2008.

Also reprinted from Campbell, 2008: Decline in price of poultry meat following introduction of coccidiostats in 1948. Annual average of monthly live-weight price of chicken per pound received by farmers (expressed in 2003 dollars calculated from data of the Federal Reserve Bank of Minneapolis, Minnesota,2006). The decline reflects an increase in the use of intensive production methods, which were made practicable by the introduction of the drugs. No attempt is made to disentangle the causative contributions of the methods and the drugs.