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Sustainable Futures

Innovation in Agriculture

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Message from the AIC President

Welcome to the inaugural issue of the Agricultural Institute of Canada's publication, *Sustainable Futures*. We chose this name for the magazine because we believe that advancing and applying innovative scientific knowledge on the sustainable use of agricultural resources can address many of the challenges facing our society, including human and animal health, food security, climate change, energy demand and biodiversity.

Sustainable Futures presents information on the many exciting developments and innovations occurring in modern agriculture. It will feature stories on scientific breakthroughs and the adoption of new technologies that make possible the best use of agricultural resources.

This issue features an article by the recipient of AIC's new Sustainable Futures Award, Dr. Christopher Cutler. The Sustainable Futures Award recognizes a young professional who shows great potential as an innovation leader, is an integrator and communicator and is someone who understands and supports the economic, environmental and social elements of sustainability.

An Industrial Research Chair and Assistant Professor at the Nova Scotia Agricultural College, Cutler has developed a highly-respected and innovative research program in blueberry entomology that addresses issues important to both the agricultural industry and the science of sustainable crop production. His research program recognizes that the sustainability of wild blueberry production depends not only upon the development of appropriate strategies to control pests and facilitate pollination, but also that the biology and ecology of the blueberry field must be understood and respected as a natural habitat and as a place where human food must be produced in a socially acceptable manner. Read his article on **page 10.**

Other articles in this issue highlight the tremendous advances made in agricultural productivity in the past 50 years, an examination of how our food producing systems can be operated in a sustainable way, biorefining research on the prairies and the multidisciplinary work being done at the University of Alberta to meet growing demands for safe and nutritious foods, bioproducts and healthy human environments.

AIC's mission is to broaden society's knowledge and use of science and agriculture. *Sustainable Futures* will be a key contributor to helping us achieve that mission. We are making the magazine available to a wide range of producer groups, commodity organizations, scientific societies, universities and colleges, federal and provincial departments of agriculture and many others.

Sustainable Futures will complement our scientific journals—the *Canadian Journal of Animal Science*, the *Canadian Journal of Plant Science* and the *Canadian Journal of Soil Science*. The journals are published by AIC in cooperation with their related scientific societies: the Canadian Society of Agronomy, the Canadian Society of Animal Science, the Canadian Society for Horticultural Science, the Canadian Society of Soil Science and the Canadian Weed Science Society. We are proud of the journals, which are read in more than 100 countries and have close to 2,000 subscribers.

AIC also draws on the expertise of its individual members and the scientific societies in our highly successful international program. The International Twinning Partnership Program, funded by the Canadian International Development Agency, features six projects in five countries—Ghana, Ethiopia, Tanzania, Sri Lanka and Vietnam—with a seventh project and sixth country, Nepal, in progress.

Whether through the adoption of better land management and soil conservation methods, the introduction of new crops, the integration of crop and livestock production or by education and extension activities, these projects share the goals of improving agricultural production, food security and human health in poor, rural regions, while reducing the environmental risks posed by and encountered in farming.

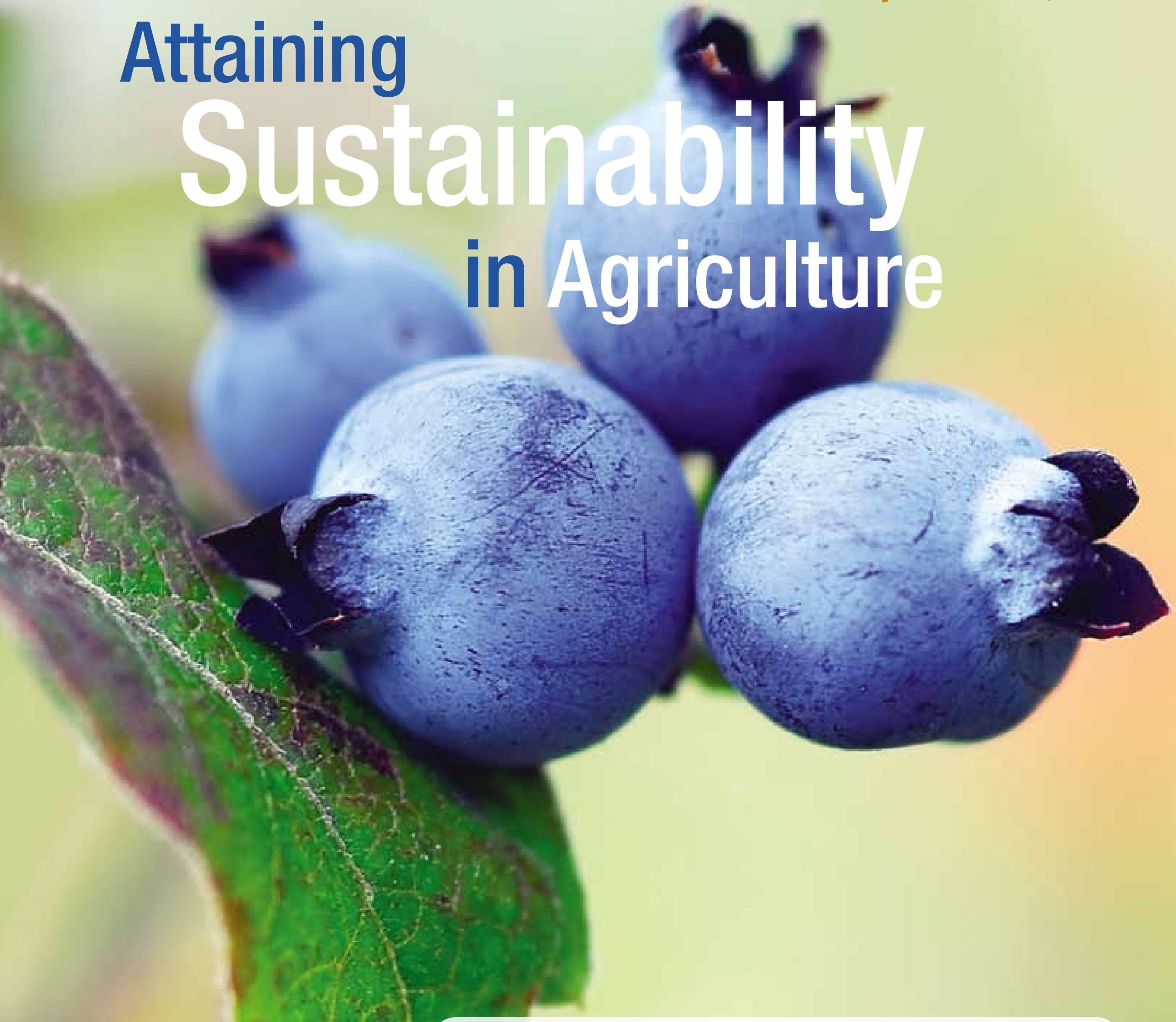
AIC's programs are all informed by our gender equality policy, reflecting our commitment that men and women will share equally in the power, decision making, work and benefits of AIC and its programs. Among a number of ongoing initiatives, AIC has requested and is analyzing gender disaggregated data on enrolment in Canada's universities and colleges with agriculture-related programs.

I feel very strongly that there has never been a greater need for a strong voice for the role of science and professionalism in the dynamic field of agriculture, especially with all of the diversity that the word agriculture has come to represent. AIC's membership includes agrologists, scientists and other professionals, the scientific societies and associations representing commodity groups. I invite you to join us.

Douglas Yungblut, PhD, PAg
President

By Chris Cutler, *Ph.D.*

Attaining Sustainability in Agriculture



Scientists and much of the general public know what *sustainable agriculture* is in the general sense. Among academics in agricultural disciplines, “sustainability” and like phrases certainly must be thrown about as much as any others. Even if one has never heard of the concept it would logically conjure thoughts of long-term farm profitability and environmental stewardship.

I often sense, however, that the importance of sustainable agriculture is greatly underappreciated. Simply in terms of area, few seem to realize how much of the Earth’s land mass is actually dedicated to agriculture, let alone how this impacts nature or human activities. The numbers are impressive. The Food and Agriculture Organization of the United Nations (FAO) estimates that 12 per cent (1.5 billion ha) of the globe’s land surface is “arable land and permanent crop,” while about one third is “agricultural area,” the sum of areas classified arable, permanent crops, temporary crops, temporary meadows and land temporarily in fallow.[1]

We obviously depend upon agriculture for food, but the influence of the farm goes far beyond that. Ecologically, the planet relies on agricultural systems to help provision, regulate and support essential ecosystem services; the converse is also true. Owing to their expanse, agricultural lands and activities have tremendous influence on biodiversity, the quality of our soils, air and water, climate regulation, nutrient cycling, food web interactions and many other processes.

Unfortunately, our agricultural systems, particularly monocultures, that are so good at producing food are relatively unstable ecologically.[2] Rapidly expanding, changing and intensified agricultural practices place great stresses on the biosphere and are often at odds with regional and global requirements for reduced environmental impact. There are high levels of fossil fuel consumption, greenhouse gas emissions, soil erosion, leaching of soil nutrients and minerals, and enormous fertilizer, pesticide and irrigation inputs. Ecological, social and economic challenges will build over the next 50 years as our population pushes toward its projected peak of over nine billion. The way we produce food will strongly determine how we meet these challenges.

GETTING THERE

Besides efforts of farmers themselves, progress towards sustainable agriculture will pick-up or falter depending on the iterative cooperation of three stanchions of society: government, the private sector, and science and technology. Our governments devise laws and treaties that we hope deliver long-term benefits to society and the planet. The development of legislation, I believe, is especially critical—where appropriate, there must be a financial reward or penalty to ensure progress towards agricultural sustainability. The second component, industry, drives society. A strong economy improves our material quality of life and allows us to plan ahead in all places that are important to us, including the environment. Government and industry together buoy science and technology to expand knowledge and secure the requisites for sustainable progress.

From a science and technology point of view, technological solutions to our sustainability challenges always seem to be trumpeted the loudest. A quick perusal of our national or provincial research funding allocations demonstrates the emphasis on technology for agriculture. Though technological solutions are always welcome, if not critical, they are not *the* solution. As Hardin[2] pointed out in his classic paper, there is a set of human problems that can be called "no technical solution problems". I view sustainability as one such problem. It is a moral and economic problem for all, and there must be technology to assist us, but it is also an ecological problem. We therefore need ecological knowledge to solve the problem. If either basic knowledge of agro-ecology or technology is deficient, future attempts by government, industry or growers to impose agricultural sustainability will very likely fail.

This bumble bee hive is outfitted with a biocontrol dispenser. Bees exiting the hive are forced to walk through a tray containing a powdered formulation of microbial antagonist. Foragers exiting the dispenser become dusted with the agent and deliver it to the target crop. Photo courtesy of Dr. L. Shipp, AAFC-Harrow.

SUSTAINABLE INSECT MANAGEMENT RESEARCH AT NSAC

Insects are incredibly successful. With over a million described species (most remain undescribed) they represent over half of all organisms known to science. Their unparalleled diversity and abundance underscores their indispensable role as providers of ecological services including: consumption, decomposition and cycling of nutrients; herbivory, predation and parasitism of other organisms to ensure population stability; and pollination services that are critical for reproduction of most flowering plants.

But because they dominate all terrestrial environments, insects are one of our key competitors for food and fibre. Economists estimate that insects consume or destroy around 10 per cent GNP in industrialized nations and up to 25 per cent GNP in some developing countries.

In my laboratory at the Nova Scotia Agricultural College, we try to tackle insect management issues from a number of angles and always keep in mind the challenge of sustainability. We study pest species, beneficial species and both technological and ecological approaches to management. As a Research Chair in wild (syn. "lowbush") blueberry entomology, I study mainly problems in, you guessed it, wild blueberry. Most of the problems we address, however, are equally relevant to other commodities. Below is a description of some of the research we do in an attempt to promote agricultural sustainability.

Insect toxicology

Despite efforts to reduce reliance on insecticides, these remain a major component of most pest management programs. Fortunately, more environmentally sound products are becoming available. We regularly test the insecticidal activity of new reduced-risk compounds and biopesticides and have identified a number of promising alternatives to conventional broad-spectrum insecticides for the blueberry industry.

By determining baseline toxicity data for new chemistries, a benchmark for insecticide resistance monitoring in the future will be established. We do laboratory and field experiments and assess not only lethal effects, but also effects on insect longevity, reproduction and other sub-lethal endpoints. The biopesticides we test are *de facto* biological controls agents, consisting of lethal microbial antagonists (e.g. insect parasitic bacteria and fungi) of insect pests that are highly sought after owing to their favourable hazard ratings and amenability in integrated pest management.

Conservation of beneficial insects is of special interest to us and we therefore study impacts of pesticides on beneficial insects, particularly pollinators. With Dr. C. Scott-Dupree from the University of Guelph, we have determined that while some new compounds appear very safe for bees, others may pose significant risks, but that risks vary depending on the bee species and exposure route. These data collectively should provide growers useful decision tools to optimize pest control while minimizing non-target impacts and environmental contamination.

Insect ecology

We study insect ecology with hopes of using this knowledge to enhance insect management. Our current insects of interest are wild bees (we have many collaborators through NSERC-CANPOLIN) and ground beetles (Carabidae). Wild bees (Apoidea) are excellent pollinators of many important crops. The Carabidae is a highly diverse family whose members feed on a wide variety of invertebrate pests and weed seeds. However, these groups are under-utilized in pollination and biocontrol, respectively, because agricultural areas often lack their basic habitat requirements, e.g. alternate forage, nesting and over-wintering sites, mainly due to a dearth of agrobiodiversity. In addition to addressing basic ecology and biodiversity questions, we hope to identify specific components of agro-ecosystems that can be manipulated to promote native insect species that hold the most promise for supplemental crop pollination and conservation biological control.

Bees as vectors of biopesticides

My lab with a team of other scientists are exploring the potential of bees to vector biological controls for plant disease suppression in blueberries, a tactic that has proved effective in other agricultural systems. The technique is user-friendly and utilizes an already present vectoring agent (bees used for pollination), which should ensure continuous delivery of fungicidal organisms directly to the blueberry plant, minimizing non-target impacts and wasted product. Growers may be spared significant time and money with less need for traditional pesticide applications while greenhouse gas emissions associated with conventional tractor spraying could be reduced.

Insect chemical ecology

Chemical ecology research has had major impacts on the field of applied entomology. Incorporation of species-specific pheromone lures into traps has provided an inexpensive and indispensable tool for mating disruption, mass trapping or insect pest population monitoring to optimize management timing and greatly decrease pesticide inputs. With Dr. K. Hillier from Acadia University, we are isolating and identifying pheromones that govern the behaviour of key insect defoliators of wild blueberry, which we hope will lead to development of monitoring tools to track populations, increase predictability of pest outbreaks and ultimately reduce chemical use.

CONCLUSIONS

Sustainable agriculture is not easy to attain but it is also not a pipe dream. As we enter an era where global food production will need to double in the face of escalating environmental challenges, food systems must minimize their ecological footprint. Interdisciplinary, multi-scale approaches offer the most promise. Commitment from consumers, farmers, industry and government is required, but I doubt dependence on the conscience alone will be enough; most of us need some financial incentive or legislation to nudge us along and here governments can play a key role in facilitating the process. We have seen excellent progress in insect management over the last half century or more. If this is emblematic of other agricultural challenges, one may be optimistic that we can reach the goal of sustainability.

I'd like to thank NSERC, NSERC-CANPOLIN, CFI, the Nova Scotia Department Agriculture, Agri-Futures Nova Scotia and their CAAP partners, the Wild Blueberry Producers Association of Nova Scotia and several other grower and industry partners for research support. Many collaborating scientists and students are involved in my research program—their contributions and cooperation are gratefully acknowledged.

Raised in King's Point, Newfoundland, Chris Cutler earned degrees from Memorial University, Simon Fraser University and the University of Guelph. He has been an Assistant Professor at the Nova Scotia Agricultural College (NSAC) since June 2007.

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BIG Changes Coming for an Environmentally Sustainable Food System

My 85-year old mother is astounded by the transformation from immigrant pioneers to the large scale, high-tech farms of today. Even more change is coming with LCA, an environmental impact tool that will have a lot to say about how we farm and how consumers purchase their food.

By Al Scholz

The truth is, the scope and scale of change by 2050 will make my mother's life experience seem incidental. In addition to the staggering challenge of doubling global food production is the environmental imperative for "sustainable food systems" and to reduce the carbon-based inputs to agriculture. It's a double whammy—how to do more with less.

Farming has to adapt. Regardless of what those involved in agriculture think, consumers are demanding it. The climate is changing—be it from greenhouse gases or long-term climate cycles—it will impact daily life and the way businesses are run.

Farmers, however, do deserve credit for completing environmental farm plans and taking action to reduce their farm's carbon footprint; yet more will be demanded, and soon.

The emergence of "buy local" and "food miles" within the context of a short growing season adds another layer of complexity, particularly in Canada which is amongst the leading nations for agricultural exports. Is our agricultural system "sustainable", and if so, how do we know and how can we measure it?

This is where the change factor comes in. There is a new environmental impact tool showing up across the global food chain. It is called "life cycle assessment" or LCA. It will provide direction on the way we farm, how food is processed and transported and how consumers make their food purchase decisions.

Best of all, this LCA tool can provide opportunities for Canada's farms to gain measurable premiums in the market place, if the right adjustments and adaptations are followed.

Developed by industrial engineers in the 1960s and 70s, LCA is a method to systematically break down any manufactured item into its components and the processes that went into making it. LCA then measures with precision the total environmental impact—from the beginning of production all the way through to final disposal, a cradle-to-grave product inventory.

Today, LCA can convert every food product into a single number that reflects everything including the carbon footprint of tractors, equipment, production inputs, chemicals, livestock feed, treatment of workers—the works. This will be the new math used in business and farming across the globe.

LCA is rapidly being adopted by agriculture and food production systems. Leading firms are already using LCA. For example, a California research group known as GoodGuide (www.goodguide.com) has developed software that allows shoppers to point their cell phone camera at the bar code of a consumer product. The picture is sent to the GoodGuide server and within seconds a three-bar rating is sent back of that very item. It reveals in red, yellow or green the relative impact of that product's life-cycle in terms of environment, health and society.

Walmart took a leadership position in July 2009 when it launched the worldwide "sustainable product index" (see http://walmartstores.com/download/3879.pdf). The purpose is to measure the environmental sustainability of all products by making its suppliers subscribe to the system. The sustainable product index is managed independently by the Sustainability Consortium, co-managed by the Arizona State University and the University of Arkansas.

On March 2, 2010, Safeway was the first major U.S. chain to join the Sustainability Consortium as a founding member—with the goal of applying LCA systems to all food products[1]. In Canada, Galen Weston, the young CEO of Loblaws has ads across Canada focusing on buying more from Canadian farmers, but only if the carbon "food print" is lower than alternative suppliers. (Search YouTube for "President's Choice – Grown Close to Home").

This level of "environmental transparency" will transform the food production system in favour of products with lower carbon footprints. Why? Because it will be very easy for consumers to see (and to reach for) more environmentally friendly products.

LCA is not always straightforward. Sometimes it gives surprising results. A classic LCA study, published in *Science* in 1991[2], was an analysis of the merits of paper versus plastic cups. The study showed that a single paper cup consumes 33 grams of wood (four packs of toothpicks) while a Styrofoam cup uses only about four grams of fuel oil or natural gas (the equivalent of half a small lighter). Both require a handful of chemicals but in the end the paper cup consumed 36 times more electricity and produced 580 times more wastewater.

Producing a paper cup had a much higher environmental cost in terms of production and disposal than plastic cups. While this was a surprise to many, it underscores the importance of accurate calculations to determine friendly from damaging when it comes to environmental impact. Watch for Tim Horton's version of roll-up-the-rim on plastic cups.

As the LCA system of full disclosure becomes more widely used, Canada's farmers can expect to be penalized in the marketplace if they leave too big a carbon footprint by using too many petroleum-based inputs.

On the other hand, farmers can expect to be rewarded by the market for production systems that are able to cycle and recycle energy and nutrients and reduce their carbon footprint, such as farms with a mix of livestock and crops that serve local markets and local processors.

But what about Canada's export based agricultural economy? While LCA is clearly not a simple calculation, it is getting easier to use with the recent emergence of several user-friendly software programs. To date there have been only a few applications for agriculture and food.

A recent study by scientists from Lincoln University in Christchurch, New Zealand reported that lamb shipped to Britain from New Zealand has a carbon footprint just 25 per cent that of British lamb[3]. This is, in part, because most of the electricity in New Zealand comes from renewable sources and their climate, with ample rain and sun, means that New Zealand pastures require less fertilizer than in cloudy Britain. Although it requires shipping across the globe, the transportation footprint (the food miles) of containers from New Zealand turned out to be less than the local trucking in UK.

The lesson is that no one should assume that local production is always more environmentally benign or, conversely, that imports always have a high environmental cost. Global trade will continue to be important in the future but the key competitive factors will increasingly move from price and quality to include environmental impact.

What does LCA hold for the family farm business model in the next ten years? Farming will become much more intensive and focus on ways to reduce the use of inputs connected to fossil fuels. As an export-based agriculture, only processed products will likely stand the carbon footprint test of long transportation distances in the future.

This may mean a marked reduction in the environmental viability of exporting raw commodities—not to mention their economic viability. The alternative is a shift to a combination of more domestic consumption (i.e. import substitution), increased livestock production and exporting products with higher value-added.

This livestock trend runs counter to current market signals, which includes criticism of animal production by environmental activists and the consolidation of slaughter facilities. However, the newly established

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national beef traceability system will give Canadian farmers and ranchers a strategic advantage in the future. It's an example of clear leadership and direct action to anticipate future market requirements.

There's still export potential for specialized cereals, oilseeds and pulse varieties, especially in boutique markets for these types of "quality-plus" commodities with specialized features. But they still must meet the "food print" environmental test for consumer acceptance and we won't really know much on this impact until more LCA analysis has been done.

There are opportunities on the horizon for Canadian agriculture and family farms, especially those that can adapt to the sweeping changes that technology allows and consumers now demand. It will be an interesting, fast-paced ride and by the year 2020, our agriculture will look (indeed it will have to look) very different.

My mother intends to live to 100 years and has the genes to do it. She figures that no generation has seen as much change as she has in her lifetime but the reality is that all she has experienced (and more) will easily be condensed into the next ten years.

Al Scholz has a graduate degree from the School of Environment and Sustainability at the University of Saskatchewan. His research focus is sustainable food systems. He has served the agri-food industry for over 25 years as an industry consultant and popular speaker at conferences. See www.awellfedworld.com.

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Innovation in Alberta

Standing on the leading edge of agricultural research, the University of Alberta's Faculty of Agricultural, Life & Environmental Sciences' tradition of finding solutions to agricultural issues is stronger than ever.

By Michel Proulx

David Bressler is the first scientist to discover a cost-effective way to convert and fractionate animal fat or crop seed oil into any of a number of fuels, including lubricating oil, jet fuel, diesel, gasoline and natural gas. The discovery, for which he's filed patents, has attracted industry attention. Bressler entered into a partnership with Sanimax through a licensing agreement to begin production of different fuels using agricultural waste.

The Alberta provincial government has also taken note and expressed its confidence by awarding $3 million to the Biorefining Conversions Network, led by Bressler. The network's goal it is to develop and commercialize novel biomass conversion technologies and value-added products. Now in its second year, the network already has 14 projects on the go.

Bressler's work is one example of the 135 natural and social scientists in the Faculty of Agricultural, Life & Environmental Sciences at the University of Alberta who are working on the leading edge of agricultural research and development.

"We are a very unique faculty in that we are science-based and we also draw on the social sciences, arts and humanities," says John Kennelly, the faculty's dean. "That allows us to seek, and I use the word very judiciously, *comprehensive* solutions to some of the key challenges we face today."

Indeed, the faculty has expertise in animal science, food science and bioresource technology, human nutrition, plant biosystems, sustainable agriculture, agricultural, environmental and resource economics as well as economics of agriculture, food and agri-business.

One major indicator of its research success—besides its enviable record of scientific discovery—is its record of attracting external research funding. In 2008/2009, faculty members generated $36 million or an average of $400,000 per continuing faculty member. At the University of Alberta, that average is second only to medicine among the institution's 18 faculties.

Kennelly suggests a few reasons for that success, namely the calibre of researchers in the faculty and the fact that the research being conducted has a direct impact on the everyday lives of Canadians.

Take canola, for example. A major Canadian crop, it generates almost $14 billion in economic activity across the country and is threatened by clubroot, a major disease. Plant pathologist Stephen Strelkov has been surveying

Habibur Rahman is a plant breeding specialist at the U of A.

Peter Boxall is at the forefront of valuating environmental goods and services.

Stephen Moore leads a team of scientists who pinpoint genetic markers that identify groups of genes or chromosomal regions.

infected fields, characterizing and isolating the strains of the disease while Habibur Rahman, a plant breeding specialist, has been using these strains in his breeding research to test new lines of canola designed to be resistant to the clubroot pathogen. Preliminary results are promising.

Meanwhile, food scientists Lynn McMullen and Michael Gänzle lead a team that has found a way to introduce bacteria into meat while it's being processed that will eliminate the threat of *E.coli.* Current food handling and sanitation procedures eliminate virtually all harmful bacteria. However, despite meat processors' best attempts to reduce risk of disease and spoilage, a form of the threatening *E.coli* bacteria still manages to survive in some cases.

By injecting an organism into meat, McMullen and Gänzle`s research shows that that if *E.coli* were transferred from the outside of the carcass during the cutting and preparation of the meat, it would be met by the 'good' live cultures which, in theory, would help control the harmful E. coli.

The faculty has also taken a leadership role in animal science. In the challenge to breed the most productive livestock, Stephen Moore leads a team of scientists who pinpoint genetic markers that identify groups of genes or chromosomal regions that are responsible for variations of a number of economically important traits such as efficiency, fatness, yield, tenderness and longevity.

To date, the researchers have generated more than 125 genetic markers for improvement of beef cattle. Twelve of these have been validated and commercialized with many of the remainder still in the technology transfer pipeline.

The group was a major player in sequencing the world's first bovine genome in 2009. Since then, Moore and his colleagues have sequenced a Holstein, an Angus and a Brazilian bull. In April, the group's global leadership in genomics research was clearly acknowledged as it received increased funding from provincial government agencies, expanded its mandate to include all livestock and changed its name to Livestock Gentec.

"Ultimately, sequencing genomes provides the livestock industries with the ability to develop quality-defined products and change its product output in the highly competitive food industry much more quickly than it ever could in the past," says Moore.

Other researchers in the faculty, led by George Foxcroft, received funding, together with colleagues from Université Laval, to establish EmbryoGENE, a pan-Canadian NSERC research network on animal embryos. The network brings together scientists looking to better understand the impact that assisted reproductive technologies and various maternal features have on swine and cattle embryos.

"We'll be looking at the environment in which those embryos are created and are forming," explains Foxcroft, Co-Director of the Network and head of the swine research node at the University of Alberta. "That will help us develop baseline data to determine normal embryos from which we'll be able to develop diagnostic tools to determine an embryo's health."

From there, researchers will examine environmental factors, most notably maternal nutrition and assisted reproductive technologies that influence the development of embryos. Ultimately, the research will be able to determine the best nutrition and conditions to produce the best eggs which will produce the best embryos and the most efficient livestock.

On the human nutrition side, a recognized area of excellence at the U of A, a major thrust of the research is focused on health issues, specifically diabetes, obesity, cancer, infant and child heath and cardiovascular disease.

Spencer Proctor is at the forefront of much of this research as he has found that a diet with enriched levels of trans vaccenic acid—a natural animal fat found in beef and dairy products—can reduce risk factors associated with heart disease, diabetes and obesity.

Trans vaccenic acid is the major natural trans fat in dairy and beef products, comprising over 70 per cent of the proportion of natural trans fat content in those products. The findings support a growing body of evidence that indicates natural animal-based trans fat is different than harmful hydrogenated trans fat created through industrial processing.

On the social science side of the faculty, it hosts the Consumer and Market Demand Agricultural Policy Research Network headed by Ellen Goddard. In fact, last October, it was awarded the network for a second time in a row.

Research projects as diverse as the demand for environmental labelling, consumer demand for traceability in livestock and meat sectors and health promotion to encourage better dietary choices of teenagers, are some examples of projects that have been funded by the network. Over the next four years, the network will distribute $1 million in funding, focusing on determining how changing consumer demand affects producers, processors and retailers by conducting research on issues such as changing consumer preferences for food attributes including food safety, biotechnology, animal welfare, environmental friendliness and health. Meanwhile, a new network was established and awarded to the university under the leadership of Peter Boxall who, together with his colleague Vic Adamowicz, has been at the forefront of valuating environmental goods and services. The new Linking Environment and Agriculture Research Network, or LEARN, will address emerging key issues such as the mitigation and reduction of agriculture's greenhouse gas emissions, adaptation to impacts of climate change, the exploration of new economic opportunities to foster environmental improvements and agriculture's impact on habitats, water quality and use.

The network's purpose is to develop and improve agricultural practices that ensure economic and environmental performance. It is expected to develop research projects in the economic valuation of environmental quality improvements in agriculture, specifically from changing agricultural practices and policy options. In addition, the network will be conducting research to develop market based instrument approaches to gain these improvements.

While the faculty boasts an impressive record of scientific discovery, it has also positioned itself well for the future. Over the last five years, it has recruited 60 faculty members and plans to recruit more over the next five years, thereby ensuring that it will continue to contribute in a significant way to finding solutions to agricultural issues facing Canadians.

Michel Proulx is the communications manager for the Faculty of Agricultural, Life & Environmental Sciences.

Biorefining Research on the Prairies

The University of Manitoba's Richardson Centre for Functional Food & Nutraceuticals is leading research on biorefining as a pathway to functional food and nutraceutical development.

By Dr. Curtis Rempel

There is a renewed interest in the role of food and agriculture in the area of human, animal and environmental health and wellness. Agriculture and food products are being looked to as a critical solution to preventing and managing chronic diseases. Agricultural production and processing are being looked to as solutions for a more sustainable environmental footprint for the planet.

The dinner plate of the future will contain functional foods and nutraceuticals which will be novel in their contribution to health and wellness. The clothing, shelter, energy and transportation of the future will include biodegradable components and fibres which will have been extracted and produced from renewable resources using "green" technologies or processes. Fractionating and/or extracting biologically active or usable compounds from plant material and incorporating these into usable products for food, feed, fibre, fuel and shelter is as old as humanity. What has changed is the sophistication of the tools utilized to derive and develop these.

Biorefining is a term used to describe biomass conversion processes and equipment to produce fuels, power and chemicals from biomass. Many also believe that these processes will yield bioactive molecules which will be important components of functional foods and nutraceuticals. There are many factors influencing the current global interest in the biorefining of biomass feedstocks to produce a wide variety of functional food ingredients, biopharmaceutical compounds, extracts, fuels and chemicals. These range from moving away from dependence of target molecules produced from fossil fuels, which will ultimately have a positive impact on climate change, to optimization of available land mass to social and economic regeneration of rural communities. Ultimately, global well-being will require using the same land, resources and plants for food, health and industrial use.

The mission of the Richardson Centre for Functional Foods & Nutraceuticals (RCFFN) is threefold:

1. Lead research on biorefining as a pathway to functional food and nutraceutical development;

2. Improve human and animal health; and
3. Support companies in their path to commercialization of these products in Manitoba, Canada and globally.

Wherever possible, we seek to develop synergies with industrial processing so that the entire harvestable component is utilized for value-added products to sustain economies and the planet.

One example to illustrate this is our ongoing collaboration with the food, fibre and chemical industries to optimize utilization of peas and edible beans grown on the Canadian prairies. The biorefining started with a functional food focus: generate pea fibre fractions and compare these versus whole pea flour. The initial project was funded by Margaret Hughes, the co-owner of Best Cooking Pulses, based in Portage la Prairie, Manitoba. Pulse Canada provided generous support for a human clinical study.

Recently, Christopher Marinangeli (PhD candidate) and Dr. Peter Jones, director of the RCFFN, completed a human clinical trial whereby subjects were fed muffins containing whole yellow pea flour, fractionated yellow pea flour or white wheat flour for 28 days. Results indicate that both whole and fractionated pea flours reduced fasting insulin and insulin resistance 20 and 25 per cent, respectively. High levels of circulating insulin in conjunction with insulin resistance have been implicated as risk factors and morbidities associated with Type 2 Diabetes and metabolic syndrome.

In addition, women consuming whole yellow pea flour demonstrated a shift in adipose tissue deposition whereby more adipogenesis occurred in thighs and buttocks verses the mid-section. Compared to central adiposity, lower-body fat deposition has been shown to pose less of a risk for cardiovascular disease and Type 2 Diabetes.

We have been employing "green" extraction and fractionation technologies in order to fractionate peas and beans. This has led to protein fractions with characteristics that are suitable for the human and animal food markets. Utilization of the fibre and protein leaves a residual starch fraction and rather than disposing of this, we have been collaborating with various groups to use the pea starch as a biodegradable polymer for packaging trays and films.

Another example is dairy whey. Whey was discovered approximately 3,000 years ago. Whey is a co-product of cheese-making and casein manufacture in the dairy industry. While highly valued as a medicinal agent in the 17th and 18th centuries, whey was, until very recently, primarily considered a waste product by the dairy industry and was typically disposed of in city or municipal sewage effluent. However, the high biological oxygen demand of whey usually leads to an overload of the system and consequently, this practice is now banned in most developed jurisdictions. There is strict legislation governing disposal of whey and individuals can be held personally liable for any breaches. Consequently, the dairy industry now faces significant disposal costs.

Research has shown that whey contains lipids, vitamins, minerals and proteins/peptides which have significant value in human health and wellness and chronic disease prevention. As whey protein contains the perfect combination of overall amino acids, it is known as a very high-quality protein, excelling over meat, vegetable (including soy) or egg. As an antioxidant, whey supports the immune system via increased glutathione levels and immune enhancement of whey has been found to be similar to human breast milk.

This has implications with respect to protection against certain types of cancer. Recent studies have shown the benefits of whey protein, particularly as it pertains to boosting the immune system and use by the pharmaceutical industry as a potential vaccine adjuvant. An added benefit of whey protein is that it may contain insignificant amounts of lactose, making this a great alternative to those individuals who experience lactose intolerance from other dairy products.

Recent published reports and unpublished observations have also indicated that a higher dietary intake of dairy whey protein (relative to total dietary protein) is associated with lower abdominal fat deposition and lower blood pressure. Increased abdominal fat and high blood pressure are indicators of health risk. This research is targeting utilization of whey protein for prevention and management of diabetes, cardiovascular disease and obesity—a cluster of disorders associated with metabolic syndrome.

This is being evaluated as a free-living dietary clinical trial in both jurisdictions. In addition to monitoring study subjects' blood pressure, the researchers are also looking at other indicators of cardiometabolic health including body composition (per cent body fat, body weight), blood cholesterol, blood glucose, arterial compliance, insulin sensitivity and resting metabolic rate. There is also some evidence that whey reduces appetite and this is being evaluated as well.

Finally, whey peptides have also been implicated in cognitive ability. Study research subjects are also being evaluated for cognitive or memory function to determine what role whey protein may play in brain function. This research is being conducted with several industrial partners and the University of South Australia, Adelaide.

Recent advances in membrane filtration have also provided new opportunities for the dairy industry to cost-effectively process whey protein. A second phase of this research is focused on the fractionation and extraction of the dairy whey peptides to enrich food and nutraceutical products. Following fractionation/isolation of the whey peptides, we have been targeting improvement of whey peptide functionality using enzymatic hydrolysis. The enzymatic hydrolysis of peptides from various sources is known to improve some of their functional properties and offers new and innovative opportunities for food applications. Hydrolyzed proteins have shown reduced allergenicity and/or improved digestibility. In this study, we are hydrolyzing whey peptides with enzymes which can be adopted by the food and pharmaceutical industry to produce whey protein fractions with added health benefit. The added health benefit of these fractions is being tested using immune, cancer and heart cells.

The chronic diseases associated with metabolic syndrome place a significant burden on our populations as well as populations globally. We believe that this research will show that metabolic syndrome can be prevented and managed using functional food products containing whey protein. We believe that this will decrease the economic cost of health care and enhance quality of life. Additionally, we believe that reducing extraction costs and developing value-added fractions with enhanced health benefits will benefit the dairy industry as well as food and pharmaceutical companies, who can use these as functional ingredients or health products.

For dairy companies specifically, this will result in lower operating costs, enhanced environmental footprint and increased value-added for what is otherwise considered an industrial waste product. So what to do with the waste stream of de-proteinized whey? There is evidence that it is a useful carbon source for biomass fermentation as well as a backbone for producing enzymes for the food and cement industry.

This concept of utilizing and adding value to everything the seed or plant biomass provides is a focal point at RCFFN for the pulse crops as well as for honey, oats, potato, flax (both seed and shive), hemp, Saskatoon berries, wild rice, soy and canola. The mission is to add value for companies so that they can realize greater revenue and employ more highly skilled people in Manitoba and beyond.

From our strategic location in the University of Manitoba's SmartPark, the RCFFN provides industry partners with a complete platform for the "biorefining," including development, testing and commercialization of functional food and nutraceutical products. This includes (a) growth and stability chambers for the enhancement of bioactives, (b) pilot scale primary and secondary bioprocessing to assist with bioactive extraction and food formulation; (c) biofermentation, (d) Natural Health Product licensed and GMP certified commercial scale tablet and capsule manufacture and packaging, (e) cell, pre-clinical animal, human clinical suites for testing safety and efficacy, (f) analytical (genomic, proteomic, metabolomic) suites for functional food and nutraceutical characterization and end-point analysis, and (g) state-of-art traditional and electronic sensory evaluation for consumer acceptability and product/market valuation.

All of these capabilities are housed in this unique centre. Industry partners also have a federally inspected pilot-scale dairy at their disposal for use in developing and testing products.

Finally, from our position in Manitoba, the RCFFN has built strategic academic, government and industry linkages on all continents of the globe and is leading or participating in many multidisciplinary collaborative approaches linked to discovery and commercialization.

Curtis Rempel, MBA, PhD, PAg, is the Research Development Manager for the Richardson Centre for Functional Foods and Nutraceuticals.

Agricultural Productivity— A Past and Future View

Each issue of Sustainable Futures will feature exciting innovations in modern agriculture. But it's also useful to take a look back to see how far we've come in the 20th century.

By Dave Hume, *FAIC*

In the 20th century, remarkable advances were made in agricultural productivity. Crop productivity per hectare in Ontario doubled, while the efficiency of most livestock in converting crops to milk, meat or eggs tripled. Overall, that meant that productivity per hectare increased about six-fold for dairy cattle, pork, chicken and eggs.

How do I know that? Fellow agrologists, Jim White, Jim Dalrymple and I spent a lot of time digging through census and historical data and putting the numbers together. Here, I want to briefly review what happened, why and what is likely to occur in the future.

DAIRY CATTLE

In 1900, most farms had a few dual-purpose "milch" cows that were milked by hand. Productivity was low. From 1900 to about 1951, there were few changes in cattle numbers or productivity per cow. In the next 50 years, production per cow tripled and numbers of cows fell to about 40 per cent of those in 1951. The net result has been about a 12 per cent increase in milk production over that 50-year period. Several things account for the huge increase in productivity per cow. One was genetics. Computerization of records allowed for identification of superior bulls. The development of artificial insemination (AI) meant a practical application of the better genetics. Later, identification of better female genetics also helped develop even better offspring. Cows got bigger

> “Transportation of both feed and birds for market has also become much more efficient. Overall, the broiler system has become much more specialized. That image I have of my mother plucking and eviscerating spent hens is only a memory.”

and more productive. More recently, ovary transplants have extended the better genetics around the world.

Rural electrification changed the dairy industry. With electricity came milking machines, which enabled farmers to increase their herd sizes. Electricity also made refrigerated milk tanks possible, which meant that milk trucks could travel to pick up the product without worrying about it going bad. Developments like milking parlours also reduced labour requirements per cow, which also allowed herd sizes to increase. Now, robotic milkers are reducing labour requirements even further. So are loose housing and automated manure-handling systems. Nutrition improvements for dairy cattle increased productivity as the requirements for high-producing dairy cows became better understood. More grain was included in the ration, corn silage became a staple, better forages were utilized and less grazing was used.

The Hon. W.A. Stewart, Minister of Agriculture, introduced dairy quotas in Ontario at about the same time productivity per cow took off. That’s no coincidence. Financial stability in the industry has resulted in greater investment in genetics, technology and research than would have otherwise occurred.

I was surprised to learn that the dairy herd on the mixed farm on which I grew up, which had about nine cows in 1951, was exactly the provincial average. Today the average herd is 55 cows but many farms are much larger.

POULTRY MEAT

Production of broiler chickens probably has been the most dramatic major change in Ontario agriculture. Between 1900 and 1950, poultry usually meant a small flock of chickens on most farms, commonly with 25 hens and a rooster or two. The numbers of hens and chickens at any one time were fairly constant between 1931 and 1961. This rose sharply between 1961 and 1971 and it’s been again fairly constant ever since. Productivity, however, has continued to go up as the number of days for broilers to reach market weight decreased. Between 1951 and 2001, broiler meat consumption in Ontario increased from 45 million kg to 342 million, or 7.6 times. Feed conversion efficiency went from 6.1 kg of gain per kg of feed down to 1.6:1. The price that farmers got paid for broiler meat increased only seven per cent between 1981 and 2001, without accounting for inflation. In 1961, Canadians consumed three times as much beef as they did chicken. Recently, chicken has passed beef.

How did the productivity increase so dramatically? As in dairy, there are many answers and a lot of them are the same: better genetics, housing, flock health and feed formulation. Prof. Richard Graham at Guelph is widely acknowledged to have been an early contributor to both genetics and management. The early research on letting chickens choose feed ingredients led to “cafeteria” feed formulations. Since then, feed formulation has been dramatically improved. Rural electrification led to better lighting and ventilation. Electric motors and computerized controls have greatly reduced labour requirements through automated feeding systems. Many of the diseases that devastated early attempts at large-scale production have been controlled through genetics, vaccines, medications and better management. Transportation of both feed and birds for market has also become much more efficient. Overall, the broiler system has become much more specialized. That image I have of my mother plucking and eviscerating spent hens is only a memory.

EGGS

The picture of eggs is much the same. Between 1931 and 2001, the numbers of layer hens remained almost constant around 25 million. The average number of eggs per hen per year, however, doubled from 133 to 260. Today, top producers achieve more than 310 eggs per hen per year. Total Ontario egg production has changed very little since 1981, hovering around 200 million dozen per year.

In the early part of the 20th century, most hens stopped laying eggs in the winter. The realization that day length greatly influenced egg-laying, coupled with rural electrification, led to year-round production. Genetic improvement was greatly enhanced by the development of hybrid laying hens. Shaver Poultry Breeding Farms of Cambridge, Ontario was a major contributor to genetic improvement of layers worldwide. In the 1950s, Shur-Gain Feeds was the first to promote all-mash rations, which replaced scratch grains. Pelletized feed further improved efficiency.

Years of research led to inclusion of vitamins A, D and E in poultry rations. More attention to mineral nutrition and vitamin D resulted in better eggshell strength. Computer-based rations with less protein and phosphorus and specific amino acid supplementation have not only increased feed conversion efficiency but had the added benefit of less manure per hen and less phosphorus and nitrogen

After this look back, we invite you to help us look forward in upcoming issues of Sustainable Futures. If you have a great story on innovation in agriculture, and with a focus on sustainability, let us know!

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in the manure. Improved flock health has been vitally important in this segment of the poultry industry. Between 1951 and 2001, feed conversion improved from 3.4 to 1.4 kg of feed per dozen eggs. In 1981, Ontario egg producers received $1.58 per dozen. In 2003, that figure was still at $1.58 per dozen.

There is an ongoing controversy about housing layers in cages as opposed to uncaged or free-range systems but caged layers have less disease, better feed conversion, easier egg- and manure-collection systems and have lower-cost egg production. It appears that cages will get bigger but are unlikely to disappear.

PIGS

Canada's swine industry is in trouble. Ontario is no exception. Two of the causes have been overproduction of pork in North America and the rising Canadian dollar. Improvements in efficiency of pork production rival those in poultry. Ontario pig numbers increased only 18 per cent between 1901 and 1951 but by 110 per cent in the next 50 years. Numbers of pigs is only part of the story.

Pork production is more difficult to calculate than dairy, broilers and eggs because imports and exports of pigs clouds the picture. We know that pork consumption increased from 122 to 312 million kg in Ontario between 1951 and 2006 or 156 per cent. Over the same 55 years, pig numbers on Ontario farms increased by only 124 per cent. The discrepancy can be partially attributed to both genetics and management improvements, included larger litter sizes and fewer days to market, even with heavier market weights. Boar numbers also decreased as artificial insemination became widespread.

Housing improved and so did herd health, which reduced mortality. Swine diseases such as hog cholera, atrophic rhinitis, erysipelas and tuberculosis have been reduced or eliminated.

As with the other livestock classes, rural electrification, electric motors, more mechanization, computerized controls, better manure handling systems, easier pens to clean and sterilize, better air circulation and temperature controls have all provided incremental improvements in efficiency. Probably the greatest improvement in feeding market hogs has been in nutrition. Feed conversion improved from 4.5 kg of gain per kg of feed in 1951 to 3.3 kg of feed per kg in 2005.

We estimated that total pork production in Ontario increased by more than two and half times between 1951 and 2001.

We have not yet done a detailed analysis of the beef cattle industry in Ontario.

CROPS

Crop productivity in Ontario has more than doubled since 1951. Grain corn is the star performer. Its yields averaged 156 bu/acre (9.8 tonnes/ha) in 2008, which was 3.6 times the average in 1950. In corn, the productivity increases are more than half genetics. Beginning after the Second World War, hybrids were introduced and improved. Increases in the understanding of soil fertility and utilization of synthetic fertilizers were major contributors to higher yield. So was the advent of chemical weed control.

Recent yield trends are sharply upward as new traits for higher yield potential, disease and insect resistance, herbicide tolerance, stress tolerance and stalk strength have combined to improve productivity. A big part of the genetic improvement in corn occurred because, as a hybrid crop, there were good financial returns to breeding companies and a lot more money invested in breeding corn rather than other crops. Over the 1951 to 2001 period, winter wheat yields increased 143 per cent, hay by 90 per cent, barley by 72 per cent and soybeans by 65 per cent.

At least three other factors were important in improving crop productivity. There was a major shift from cereals like barley and particularly oats, as the horse population dropped, toward corn and soybeans. Fewer acres were required for pasture. Farm machinery for planting and harvesting also improved, dramatically reducing the on-farm labour requirements.

ACRES REQUIRED

We took the data for the amounts of poultry and pig meat, eggs and milk produced in 1951 and 2001 (census data), used typical rations and feed conversion efficiencies for each period and calculated how many acres were required to produce the amounts of those foods in Ontario. Ontario's population increased 150 per cent but livestock productivity (excluding beef) tripled and crop yields doubled. It turned out that the chicken, eggs, milk and pork produced in 2001 to feed 11.4 million people actually required 42 per cent less farmland than was required in 1951 to feed 4.6 million people.

Those huge increases in agricultural productivity have freed up space for housing, recreational space, infrastructure, industry, forests and wetlands. Also, since 1961, the proportion of disposable income spent on in-home food has decreased from 19 to nine per cent. Today, that means more than $8,000 after-tax per year for a family of four.

THE FUTURE

My cloudy crystal ball says many of these trends will continue. I expect to see corn yields, for example, continue to increase as traits, already on the horizon, like drought tolerance, disease and insect resistance and higher yield potential, come into production. Soybeans have been on a yield plateau for the last three decades but top yields in U.S. high yield contests are now triple those of our best yields. I expect to see provincial winter wheat yields improve dramatically too. Top producers are close to double the provincial average. There is still a lot of room for improvement.

Every time I thought the world might starve, grain prices went up, farmers responded with an enormous increase in productivity and agriculture had that "Challenge of Abundance" again. Fifty years ago, I would have thought that the impressive gains seen in productivity in the livestock sector were impossible. I expect animal productivity to continue to increase, although I think a lot of the low-hanging fruit has been picked and the improvements will not be as spectacular as they have been in the past half-century.

Dave Hume has been a faculty member since 1966 at the University of Guelph.

For more details, visit www.uoguelph.ca/oac/news/documents/Livestock_Industry_in_Ontario_102208.pdf

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