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BALANCING ELEPHANTS **Saskatchewan's Return on Investment** **AG-WEST BIOTECH INC.**

BY GERARD A. LUCYSHYN



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Saskatchewan's Return on Investment
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EXECUTIVE SUMMARY

The *theory of path dependency* refers to decisions made at a single moment in time, where such decisions and the conditions surrounding those decisions almost irreversibly affect occurrences which ultimately produce an outcome.¹ The decision made by the Saskatchewan government in 1980's to form Ag-West Biotech Inc. bridging the gap between Saskatchewan's agricultural biotechnology research sector and the marketplace is an example of path dependency. This decision placed Saskatchewan on the path to become the forefront of agricultural biotechnology research and contributed in making Saskatchewan an epicentre of research and development. Between 1989-2002, the Saskatchewan government provided funding of \$13.5M to Ag-West Biotech Inc. This funding would return \$48.3M direct private investment into Saskatchewan's agricultural biotechnology sector and increase Saskatchewan's GDP by \$424.7M, yielding an exponential return on investment for Saskatchewan.

This paper takes the reader through the economics of agricultural biotechnology and the development of Ag-West Biotech Inc. Using the amount of funding received by Ag-West Biotech Inc. between 1989-2002 along with the economic gains by Saskatchewan, the paper calculates Saskatchewan's simple rate of return on this investment.

TABLE A				
ROI Summary				
	ROI Calculation	ROI (GDP)	ROI (Product Sales)	ROI (Private Investment)
13.5 Million Invested	14 yr. ROI	3046%	2237%	257.8%
	Avg/Yr ROI	217.7%	159.8%	18.4%
	Benefit Cost Ratio	31.5	23.4	3.6
	IRR (Nominal)	153.3%	84.3%	49.8%
	IRR (CPI)*	151.1%	83.3%	48.8%
	IRR (Bond)**	133.1%	72.5%	41.7%

* Discounted by Saskatchewan CPI Yr over Yr (All goods base year 2002) 1989-2002.

** Discounted by Annual Average Weighted Yield Provincial Long Term Bonds 1989-2002.

PRINCIPLES OF MENDELIAN INHERITANCE:

Agricultural Biotechnology

“The value and utility of any experiment are determined by the fitness of the material to the purpose for which it is used, and thus in the case before us it cannot be immaterial what plants are subjected to experiment and in what manner such experiment is conducted.”²

- Gregor Mendel, Experiments in Plant Hybridization, 1865

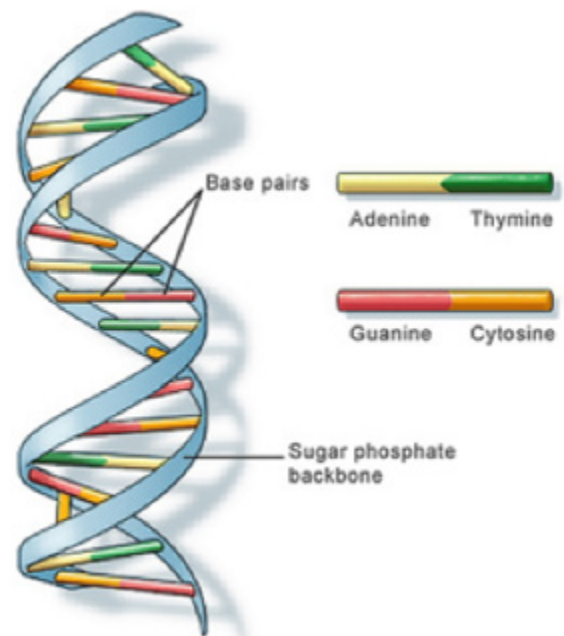
Many non-scientists may not be aware just how integrally related agricultural biotechnology is to our everyday lives, in fact, many of our common modern day grains, fruits and vegetables that we consume such as rice, wheat, grapefruit, and lettuce are the result of changes made to the DNA sequence of other plants.³ Agricultural biotechnology has been apart of society dating back as far as 10,000 BC when humans began to domesticate crops and livestock. Through history, producers have always attempted to selected better plants and better animals in order to improve their harvests and breeding stocks. Often their selection was done to isolate desirable traits such as different crop varieties, increased nutritional values, adaptation to different climates, and for resistance to diseases and pests. For example, subsequent to 1492, European growers adapted corn to suit the growing conditions in Europe after they were introduced to it in the Americas.⁴

There are many other examples of agriculturalists experimenting with selective breeding of crops and livestock but it was in 1870 that agriculture would be revolutionized with the discovery of the rules of inheritance. The rules of inheritance form the fundamental theory of heredity, that is, the passing of genes from parents to offspring. The theory of heredity that would provide agriculturalists with a comprehensive understanding of inheritance and launch the modern age of genetics.⁵

Deoxyribonucleic acid (DNA) is the hereditary material contained in cells of all living things. The basic structure of DNA is identical from one organism to the next. DNA base pairs are made up of four chemical bases: adenine (A), guanine (G), cytosine (C), thymine (T). A base pair is where two of the four chemical bases pair with one another. For example adenine pairs with thymine and cytosine pairs with guanine. The base pair is attached to a sugar and phosphate molecule forming a nucleotide (also known as a double helix or a gene — Figure 1).⁶

FIGURE 1

Double Helix (Gene)



Source: U.S. Library of Medicine.
<https://ghr.nlm.nih.gov/primer/basics/dna>.

Different characteristics in organisms is the result of the difference in sequencing of the DNA base pairs, similar to how letters in the alphabet arranged in a certain order forms different words and sentences. In biotechnology, researchers can take a distinct gene and transfer it to other organisms, essentially taking a heredity unit from any plant, animal, bacteria, or virus and introduce it to another.⁷ Different genes are the reason why same species do not share the exact same traits.⁸ For example, the colour of fruits and vegetables are controlled by different genes, the first cultivated carrots were purple or yellow.

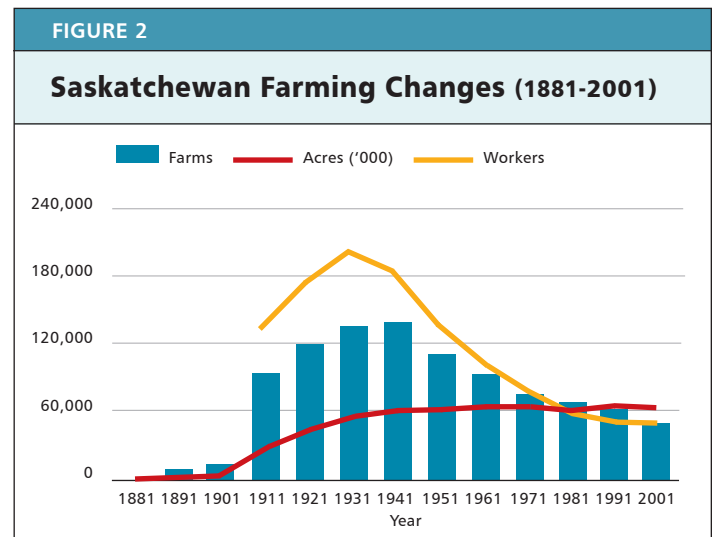
As mutations occurred by crossing them with wild varieties it resulted in the modern day orange carrot. Whether a carrot is orange, white, yellow, red, or purple all depends on the different combination of genes.⁹

Agricultural biotechnology has always played an important role in the history of Canada, especially across the prairie provinces. Two years after the development of the rules of inheritance, the first government of Canada under the leadership of Sir John A. MacDonal, passed *An Act Respecting the Public Lands of the Dominion* (known as The Dominion Lands Act 1872). This Act established the rules for the settlement of western Canada.¹⁰ The Dominion Lands Act granted settlers 160 acres if they filed a land claim for a designated area, cleared at least 10 acres, and built a residence within three years of settling on the land. Over 750,000 new settlers would eventually relocate from the United States and Europe between 1872 and 1918 into the North-West territory which transformed into the prairie provinces of Alberta, Saskatchewan, and Manitoba.¹¹

In the early years of settlement, oats and wheat were the two main crops planted. Oats were used for animal feed, while wheat was a commodity crop. Originally the wheat species that was planted was Red Fife which was native to Galicia (modern day Ukraine).¹² In 1904, grain researcher Charles Saunders from Ottawa, crossed hard Red Calcutta with Red Fife to develop an early-ripening variety, Marquis wheat. Marquis wheat was introduced to prairie farmers in 1909¹³ and to the international market in New York in 1911 by Saskatchewan farmer Seager Wheeler from Rosthern at the land show.¹⁴ By 1918, Marquis wheat would occupy 80-90% of the total wheat acreage planted, covering more than 20 million acres from southern Nebraska to northern Saskatchewan. Marquis wheat would also go on to be planted by every wheat producing country in the world.¹⁵

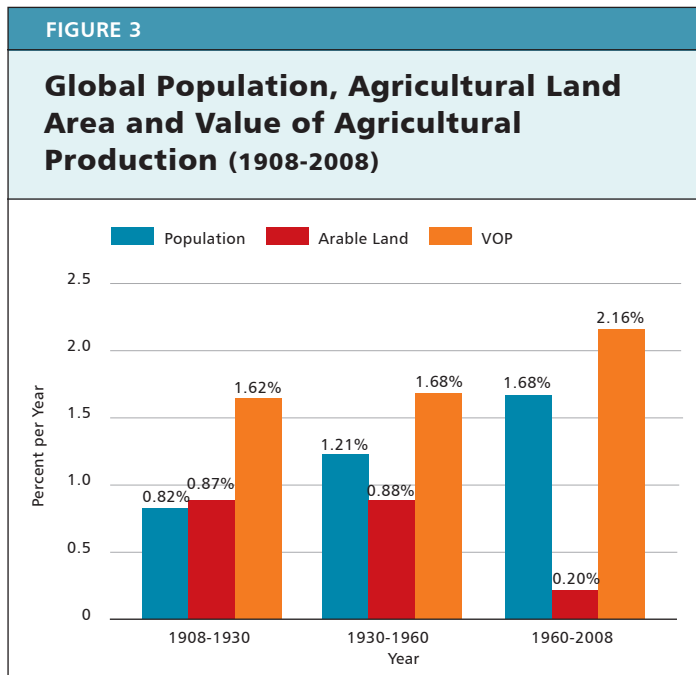
The Prairie provinces continued to play a central role in the revolutionization of agriculture with the development of other new types of crops such as, Canola (abbreviation for "Canadian Oil")¹⁶ and the expansion into alternative crops such as, lentils, field peas, and chickpeas. Prairie innovation and diversification was not only restricted to commodity crops; Saskatchewan producers would also diversify into new breeds of cattle and other types of livestock, such as bison, elk, llama, and ostrich. Prairie producers have always been quick to adopt new agricultural practices and technologies as they developed such as direct seeding, zero tillage, and planting and harvesting with global position system (GPS).¹⁷

With the enormous changes in technology, production levels, costs, and levels of efficiency in agriculture since 1870, across the globe and the Canadian prairies there was a decrease in the need for basic farm labour as the average farm size increased. At its peak, in 1936, Saskatchewan had 142,391 farms with farm holdings of 56.9M acres and 200,881 agricultural workers.¹⁸ By 2001 the number of farms had drastically reduced by 74% to 36,952 and farm holdings slightly increased by 13% to 64.3M while agricultural workers dramatically decreased by 74.1% to 52,100 (Figure 2).¹⁹



Source: Stats Canada.

As producers adopted enhanced agricultural practices and technology, the quality and quantity of crops increased reducing the amount of time and resources used for food production. The improvements in productivity and agricultural practices improves the lives of people; as food becomes more abundant and easier to obtain, it allows individuals to focus on other activities (Figure 3).



Source: OECD Conference on Agricultural Knowledge Systems, 2011.
<http://www.oecd.org/tad/agricultural-policies/48165448.pdf>.

ECONOMICS OF AGRICULTURAL BIOTECHNOLOGY

“If you look at ag-biotechnology and the work that’s being done in Saskatoon, partly by the Research Council, partly by other entities, the development of agricultural biotechnology really is, I think, the future of the agricultural industry in western Canada and particularly in Saskatchewan. So we really are working hard on this and want to see a very much enhanced research and development capacity and capabilities here in our province.”²⁰

*- Hon. Eldon Lautermilch,
Saskatchewan Minister of Energy and Mines, 1998*

Successful agricultural research enables farming productivity and food production to increase. Increasing food production assists in breaking the poverty cycle and creates food security.²¹ As the food supply increases, the price of food decreases, and people’s real income increases. With an increase in their real income, people are able to purchase more food and other essential services, such as housing, healthcare, and education. Economically speaking innovation in agricultural research and technological frees labour from subsistence production and reallocates that labour to other productive areas within an economy, such as, manufacturing, entrepreneurship, and knowledge industries. In fact, throughout the world it has been demonstrated that gains in agricultural productivity stimulate broad economic growth in a country.²² As a major engine of economic growth, governments around the world have made major public investments into agricultural research. The United States, China, India, and Brazil, all have heavily invested into basic biology research, medical biotech, and agricultural biotech research.²³

The current biotechnology sector began to develop in the 1970’s. At first, government funding was directed into university-based research. By the 1980’s research began to move from universities into the private sector where a wide array of small and medium sized research firms were established. However, by the end of the 1980’s several large pharmaceutical, chemical and

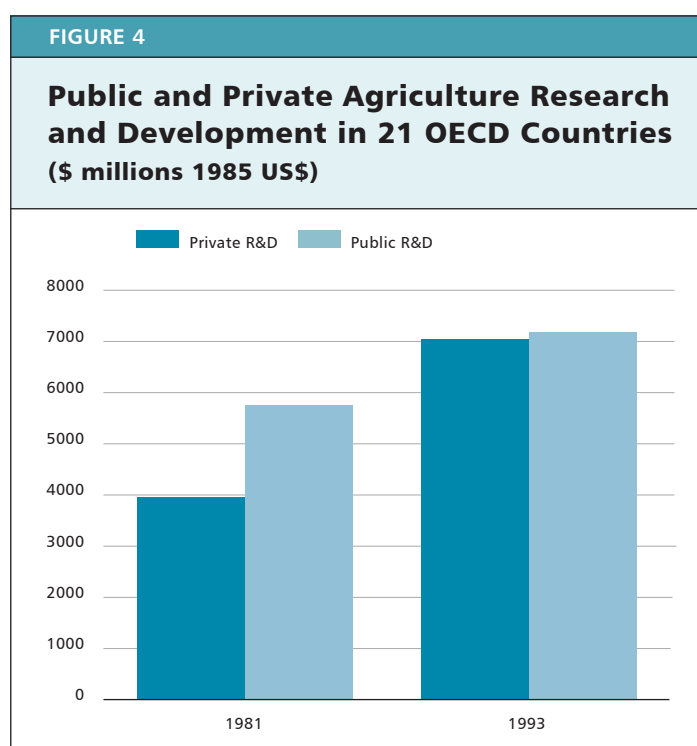
TABLE 1			
Global Public Agricultural Research Expenditures (1976-1995)			
Millions 1993 International Dollars			
Expenditures	1976	1985A	1995A
Developing Countries (119B)	4,738	7,676	11,469
Sub-Saharan Africa (44)	993	1,181	1,270
China	709	1,396	2,063
Asia and Pacific (Excluding China) 23	1,321	2,453	4,619
Latin America and Caribbean (35)	1,087	1,583	1,947
Middle East and North Africa (15)	582	981	1,521
Developed Countries (34)	7,099	8,748	10,215
TOTAL	11,837	16,424	21,692

Source: Pray, Carl E. and Anwar Naseem. "The Economics of Agricultural Biotechnology Research". ESA Working Paper No. 03-07. Agriculture and Economic Development Analysis Division. The Food and Agriculture Organization of the United Nations. June 2003.

seed companies established in-house research facilities and the biotechnology sector became competitive between private research firms and their public-funded counterparts.²⁴

Globally the amount of public agricultural research expenditures between 1976-1995 increased 83% from \$11.8B to \$21.6B (Table 1). This relatively large rate of growth would nearly cease in most developing countries in the mid 1990's as the level of private expenditure increased and governments were facing massive deficits. Although private expenditure would closely match the level of public funding, both types of funding begin to level off as negative consumer perceptions about agricultural biotechnology increased, as well as, an increased public pressure on governments for increased environmental regulation.

In agricultural research there is a significant difference between private investment and public investment. Private investment is made in an attempt to develop new products and technologies to make a profit for the research firm; hence, any research project must demonstrate a promise of profitability. Whereas public investment is made in an attempt to improve the welfare of the population, as such, any research project must yield substantive and apparent social benefits along with political credit.²⁵ Usually the basic justification for public expenditure on agricultural research is that private firms will have a tendency to underinvest in research that contributes to a public good,²⁶ since public



Source: Pray, Carl E. and Anwar Naseem. "The Economics of Agricultural Biotechnology Research". ESA Working Paper No. 03-07. Agriculture and Economic Development Analysis Division. The Food and Agriculture Organization of the United Nations. June 2003.

goods provide social benefits not profits (Figure 4).

Regardless of source of investment, public or private, agricultural research is risky and has high costs. Conducting agricultural research requires scientists, labs, chemicals, electricity, experimental fields, agricultural inputs, product testing, consumer demand

analysis, and marketing.²⁷ The costs of these items are directly related to the quality, quantity, price, duration of use, and the current stock of knowledge within the field being researched. It is important to understand that failure to develop a new viable product or create new knowledge or failure to get the new product to market, any costs of associated with that research become sunk and unrecoverable.

Another risk factor with agricultural research is, even with successful development of a product or new knowledge, an unfavourable business environment, economic downturn, or impeding government regulation or policy can easily turn a viable product into a complete waste of time and resources.²⁸ Policymakers who fail to ensure appropriate incentives and government regulations, such as intellectual property rights and market freedom, hinder the biotechnology sector to function and increase the risk of investing into research, turning successful research into a waste of valuable resources and a futile effort.

“Public agricultural research is justified because it provides public goods; goods that yield social benefits that cannot be captured by private firms and thus will not induce optimal private investment. Public research investment responds to markets for innovations and costs of research like a private firm but must fulfill political as well as financial goals.”²⁹

- Carl E. Pray and Anwar Naseem,
The Economics of Agricultural Biotechnology Research, 2003

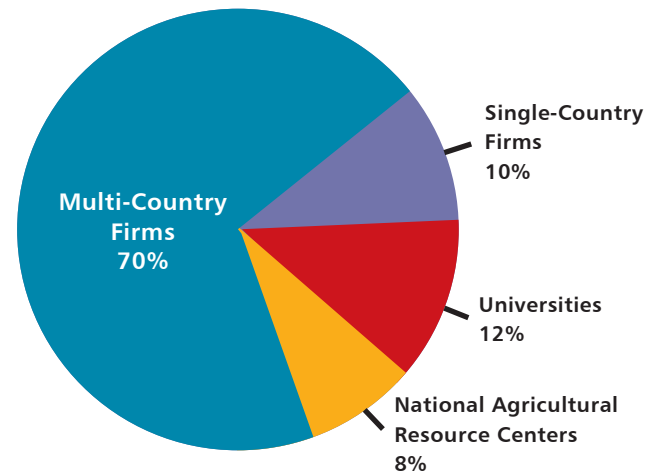
In 2002, the Organisation for Economic Co-operation and Development (OECD) indicated that a successful biotechnology sector includes a strong scientific base built around top-rated academic institutions (Figure 5). These institutions must be willing to engage in groundbreaking research that provide incentives for top scientists to relocate to those institutions. However, the most important component is commercialization of newly developed products or knowledge that capture either profits or the social benefits. The commercialization of new products and knowledge

requires the ability to foster private venture capital investment.³⁰

There are a number of ways to measure the success of investment into agricultural biotechnology. One method is to measure the ability of a company to foster private venture capital investment. Another method is to assess the social benefit and social rate of return. The social rate of return on agricultural research is measured in terms of the reduction in costs of agricultural production that was directly related by the research, or by measuring the annual benefits in terms of how much the supply of the agricultural product increased due to the new technology. A third method is using econometric estimates of the impact of research on agricultural productivity, agricultural costs, or agricultural profits.

FIGURE 5

Public and Private Research (Field Trials) of Genetically Modified Crops in Industrialized Countries (1987-2000)



Source: Pray, Carl E. and Anwar Naseem. "The Economics of Agricultural Biotechnology Research". ESA Working Paper No. 03-07. Agriculture and Economic Development Analysis Division. The Food and Agriculture Organization of the United Nations. June 2003.

A large number of studies measuring the rates of returns on government investments in agricultural research have been conducted by agricultural economists since the 1970's. These studies, in general, illustrate that public investments in research are a very good government investment.³¹

LEADERSHIP IN AGRICULTURAL BIOTECHNOLOGY:

Ag-West Biotech Inc.

“The investments our government is making in ag-biotech and throughout that whole area of research in agricultural products, Mr. Speaker, is going to lead us into a green and prosperous future. It’s going to lead us into a future where young people have jobs not just in the cities but in rural Saskatchewan.”³²

- Hon. Mark Wartman, Saskatchewan Minister of Agriculture and Food, 2004

During the 1980’s the Saskatchewan government along with the University of Saskatchewan identified a gap between agricultural research and the ability to bring that research to the marketplace.³³ Ag-West Biotech Inc. (AWT) was launched in 1989 with the specific mandate to provide leadership and assistance to Saskatchewan’s Ag-biotech sector through assisting existing biotech companies to grow and aid them to commercialization

new biotechnologies.³⁴ AWT fulfilled its mission through public education on the biotech sector with a variety of publications, websites, workshops and seminars; in addition, AWT assisted numerous companies with start-up financing and assisted these companies to bring their products to market. As a key member of the biotech sector, AWT also played an important role in advancing Canada’s regulatory system with respect to biotechnology.³⁵

Six years after its inception, in 1997, AWT amalgamated with the International Centre for Agricultural Science & Technology (ICAST). Between 1997-2004, AWT operated the Saskatchewan Agricultural Biotechnology Information Centre (SABIC). SABIC was Canada’s first publicly accessible demonstration laboratory and resource center intent on increasing public understanding of agricultural biotechnology.³⁶ The SABIC program was extremely successful boosting over 12,000 visitors and having subscribers from over 45 countries.³⁷

AWT efforts in assisting local Saskatchewan companies to establish themselves (Table 2), and pursuit international biotech companies to relocate to Saskatchewan proved successful (Table 3). As of 2002, Saskatchewan made

TABLE 2	
Examples of Local Saskatchewan Agricultural Bioproduct Firms Formed Between 1989-2002	
Alphafibre (Weyburn)	Natural fibre composites
Biolin Research (Saskatoon)	Processing flax straw into linen and other textiles
Bioriginal Food & Science Corp. (Saskatoon)	Processing nutraceuticals
Durafibre (Canora)	Processing flax fibres into specialty papers and fibre board for the auto industry
Fytokem Products Inc. (Saskatoon)	Developing plant extracts and phytochemicals
Nuform Packaging (Tisdale)	Markets recycled fruit packaging to U.S. and Canadian fresh fruit industry
Parkland Strawboard (Kamsack)	Production of wheat-based strawboard
Parrheim Foods (Saskatoon)	Manufacturing of peas starch, protein concentrates, and dietary fibres by wet-processing methods without adding chemicals to the finished products
Urban Forest Recyclers - UFR (Swiftcurrent)	Manufacturing of chemical egg trays from recycled materials including flax and canary seed straw as fibre strengtheners in their processing

Source: Mitura Economic Research Inc.³⁹

TABLE 3

Examples of International Companies Actively Involved in Crop Research and Bioproduct Development in Saskatchewan (1989-2002)

DowAgro Sciences	Brings innovation of life through people, chemistry and biotechnology in the areas of seed and crop production and pest management. Headquartered in Calgary with commercial and research operations across Canada. Key research facilities include corn and soybean breeding in St. Mary's and a global canola research centre in Saskatoon.
Monsanto Canada	Committed to developing the technologies that enable farmers to produce more crops while conserving more of the natural resources that are essential to their success. Selling seeds, traits developed through biotechnology and crop protection chemicals.
Pioneer He-Bred	(DuPont Pioneer) is a large U.S. producer of hybrid seeds from agriculture. They are a major producer of genetically modified organisms including genetically modified crops with insect and hybrid resistance.

Source: Mitura Economic Research Inc.⁴⁰

up 30% of the Canadian agricultural biotechnology sector and had created nearly 500 new biotechnology products.³⁸

Saskatchewan was the largest Canadian supplier of agricultural materials to domestic and international markets. Saskatchewan developed agricultural bio-products that included: agro-fibres, specialty oils, therapeutics, renewable energies, bio-lubricants, feeds, agricultural co-products (grain screenings, oil press cakes).⁴¹ At that time the Canadian bio-industrial market was estimated at \$50B per year, with Saskatchewan controlling 30% of the market, approximately \$15B.⁴² By 2004, Saskatchewan boasted the largest renewable bio-product sector in Canada and became home to Canada's national centre for synchrotron research.⁴³ With the development of the Canadian Light Source (CLS), a world-class state-of-art facility located in Saskatoon at the University of Saskatchewan, Saskatchewan was well on its way to becoming an epicentre of research.⁴⁴

In the same year, AWT amalgamated with Bio-Products Saskatchewan and the Saskatchewan Nutraceutical Network to form the current Ag-West Bio (AWB).⁴⁵ The newly formed Ag-West Bio adopted a much broader mission than its predecessor. AWB's mission is to focus on the commercialization of biological applications

in agriculture, the environment, industry, energy, bioprocessing, nutrition, and health.⁴⁶

AWB is a not-for-profit membership-based company that continues to operate as a catalyst for the bioeconomy in Saskatchewan.⁴⁷ Through collaborating with entrepreneurs and matching them with mentors and providing funding in early stages of product development, it continues the work of its predecessors.⁴⁸ At the time of the merger AWB membership included public research institutions, private companies (from startups to multinational companies), research service organizations, economic development and commodity groups (Table 4).⁴⁹

AWB continues to host networking events, conferences and seminars, and assists the biotechnology community stay connected and informed. AWB also leads delegations to relevant international conferences and assists in arranging incoming delegates interested in finding partnerships in Saskatchewan. AWB is funded by the Saskatchewan Ministry of Agriculture and Agriculture & Agri-Food Canada's Growing Forward II program and is supported by the Western Economic Diversification Canada and the National Research Council's Industrial Research Assistance Program.⁵⁰

TABLE 4

Corporate and Associate Members of AWB (2005)

<p>Agricultue Agrifood Canada</p> <p>Bayer Crop Science Becker Underwood Inc. BioAlberta Bioriginal Food and Science Corp. Botting Leadership & Development Corp. British Columbia Functional Food and Nutraceutical Network</p> <p>Canadian Bioenergy Association Canadian Health Food Association Canadian Institute of Food Science Canadian Light Source Inc. Cevena Bioproducts Inc Chromatin, Inc. Clear-Green Environmental Inc. Contact Canada</p> <p>Dow Agrosiences Canada Inc. DSG Canada</p> <p>Emerald Seed Products Ltd. ERCO Worldwide</p> <p>Foragen Technologies Mgmt Inc. Fytokem Products Inc.</p> <p>Genome Canada Genome Prairie Guardian Biotechnologies</p> <p>Heads-Up Plant Protectants Hodgins and Company Management Consultants Inc.</p> <p>Industry Liason Officer, University of Saskatchewan InfraReady Products 1998 Ltd. Innovation Place Investment Saskatchewan</p>	<p>Laprell's Beehive Products Inc.</p> <p>Maple Leaf Bio-Concepts Manitoba Food Processors Association Milligan Bio-Tech Inc.</p> <p>National Research Council New Era Nutrition Nipawin Biomass Ethanol - New Generation Co-op</p> <p>Performance Plants Inc. Plant Biotechnology Institute POS Pilot Plant Phenomenome Discoveries Inc. Philom Bios Inc. Pioneer Hi-bred Ltd. Prairie Agricultural Machinery Institute</p> <p>Centre Quebecois de Valorisation des Biotechnologies</p> <p>Sangster's Health Centres Saskatchewan Environmental Industry and Managers Association Saskatchewan Flax Development Commission Saskatchewan Fruit Growers Assoc. Saskatchewan Food Industry Development Centre Saskatchewan Herb & Spice Assoc. Saskatchewan Industry and Resources Saskatchewan Research Council Saskatchewan Trade and Export Partnership Saskatoon Chamber of Commerce Saskatoon Regional Economic Development Authority Saskatoon Research Centre</p> <p>The Saskatoon Colostrom Company Ltd.</p> <p>University of Saskatchewan, College of Agriculture University of Saskatchewan, College of Commerce</p> <p>VWR International, Inc.</p>
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Source: Mitura Economic Research Inc.

“When Ag-West Bio was founded, not a single genome had been sequenced. Today genomics is an important tool in all areas of biotech research. With world-class infrastructure, talent and a positive business climate, Saskatchewan is an exciting place to be involved in biotechnology.”⁵¹

- Wilf Keller, President of CEO of Ag-West Bio, 2014

CALCULATING SASKATCHEWAN'S RETURN ON INVESTMENT (ROI)

“The work that Ag-West Bio has done in the last 25 years has had a real impact on the productivity and profitability of our producers”⁵²

- Hon. Lyle Stewart, Minister of Agriculture Saskatchewan, 2014

Return on Investment (ROI) is the most common performance measure used to evaluate an investment, especially when comparing it to other investment options. ROI measures the amount of money earned, or the return, on an investment relative to the cost of that investment. Calculating a simple ROI is achieved by dividing the benefits received from the investment by the cost of the investment and expressing it as a percentage:

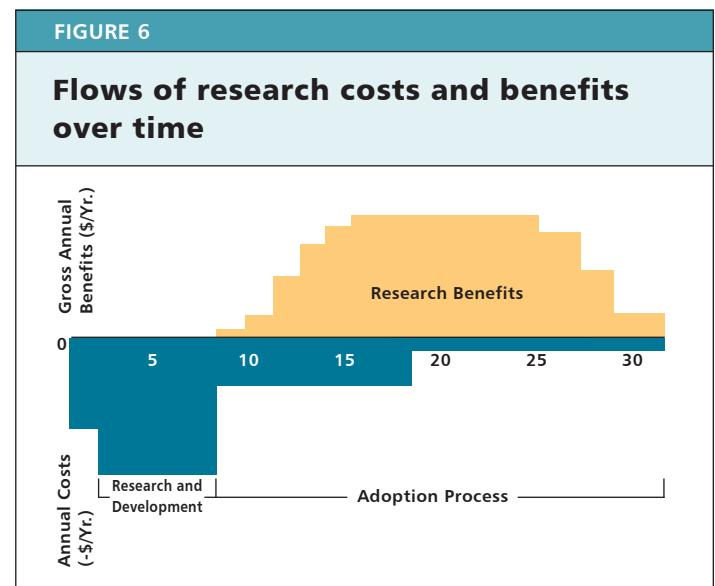
$$\text{Return on Investment} = \frac{\text{Gain from Investment} - \text{Cost of Investment}}{\text{Cost of Investment}}$$

“Gains from Investment” are the proceeds obtained from the sale of the investment whereas the “Cost of Investment” is the actual amount paid out for the investment. The challenge in calculating an accurate ROI arises when deciding on what were the actual gains received from the investment; that is, if the gains or costs of the investment occur over a time period this may complicate the simple calculation. It is very important to ensure that the gains and costs are properly accounted otherwise the measurement will be incorrect and interpretation of the return on investment will be flawed. Leverage Investments allow the initial investment to be multiplied many times over and can generate multiple returns. If the investment is over time then it is also advisable to discount or take into account the inflation rate allowing people to calculate the real ROI rather than a nominal ROI. Another complication arises when calculating ROI for a not-for-profit investment or an investment in a public good, since the gains from the investment cannot be simply measured in terms of profits or dividends. AWT has always operated as a not-for-profit organization both pre- and post- the 2004 merger.

“Agricultural research generates long-term benefits. An investment in research entails a long lag time before it produces tangible economic impact is well understood. It is also clear that the lag is longer for more basic research than for more applied research, and that a sizeable share of research undertaken may never be applied to technology development that is adopted by farmers.”⁵³

- United States Department of Agriculture, Economic Research Service, 2007

When performing an economic evaluation of an investment in agricultural research the following comparisons could be made: (i) public and private investments in agricultural research, and (ii) the long-term effects on agricultural productivity. This paper performs an economic analysis on the return of publicly funding AWT. Therefore, the economic evaluation must weigh the costs expended on AWT against the economic benefits gained. Since the expenditure and benefits accrued over time, discounting is necessary to measure the return without inflationary effects. Note that the typical time frame between development and the adoption of technology in agricultural research is close to seven years (Figure 6).⁵⁴



Source: Fuglie, Keith O. and Paul W. Heisey. United States Department of Agriculture Economic Research Service. “Economic Returns to Public Agricultural Research”. Economic Brief Number 10. September 2007.

Between 1989 and 2002, AWT received funding from the Saskatchewan government totalling approximately \$13.5M (Table 5).⁵⁵ Approximately 30% was used for operations of AWT while 70% was used for direct Investments into new initiatives. AWT invested approximately \$9.3M in forty-six different projects involving thirty-seven different companies.⁵⁶ Fourteen of these investments were for the development of new technologies for commercialization. Eleven investments were to aid in the development of new varieties and new uses for the existing crops of canola, flax, potato, oats and mustard. Seventeen investments were to assist in the development of new livestock vaccines, nutraceuticals, fertilizer applications, and various food and medicinal products. Four of the investments were to build capacity within public institutions, and three investments were to assist multinational agrochemical companies to relocate to Saskatchewan.⁵⁷

Out of the fourteen companies that received financing from AWT to develop new technologies for commercialization, twelve of them introduced new products to the market. Between 1992 and 2002, these companies had reported gross sales for those products of \$315.5M.⁶⁸ Overall, the average lag time between investment and market introduction for those products was approximately three years, half the statistical average for most agricultural research to achieve adoption. Out of the forty-six investments (100%, ~ \$9.3M) made by AWT prior to the merger in 2004, seventeen investments were ongoing (31%, ~2.9M) and actively being repaid, eight investments were repaid (24%, ~2.2M), and twenty-one investments were written off (45%, ~4.2M). While nearly 45% of these projects were written off. AWT was very prudent in its investment choices as the average leverage ratio on the investments was 6.7:1, which is well under the acceptable industry standard of 9:1.⁶⁹

TABLE 5	
Saskatchewan Public Expenditure on AWT Between 1989-2002	
Budget Year	Research and Technology (AG06) ⁵⁸
1989-1990 *	\$ 1,043,351
1990-1991 *	\$ 1,043,351
1991-1992 *	\$ 1,043,351
1992-1993 *	\$ 1,043,351
1993-1994 ⁵⁹	\$ 1,146,000
1994-1995 ⁶⁰	\$ 1,020,665
1995-1996 ⁶¹	\$ 789,954
1996-1997 ⁶²	\$ 930,956
1997-1998 ⁶³	\$ 1,087,291
1998-1999 ⁶⁴	\$ 1,100,000
1999-2000 ⁶⁵	\$ 1,100,000
2000-2001 ⁶⁶	\$ 1,100,000
2001-2002 ⁶⁷	\$ 1,100,000
Total Funding	\$ 13,358,272

* 1989-1993 estimated budget based on 9 year average funding between 1993-2002.
Source: Government of Saskatchewan, Public Accounts 1989-2002.

AWT projects encouraged an additional \$52.5M of outside investment into Saskatchewan's ag-biotechnology, of which \$4.2M came from other public sources, such as Agriculture and Agri Food Canada (AAFC), Industrial Research Assistance Program (IRAP), Agri-Food Innovation Fund (AFIF), and Northern Alberta Business Incubator (NABI) and the remaining bulk of \$48.3M coming from private sources.⁷⁰ Nearly all the \$61.8M invested from all sources was spent on Saskatchewan-based salaries and on goods and services in Saskatchewan, very little was spent on out of province purchases.⁷¹ The contributing effect of AWT operations between 1989 and 2002 was approximately \$424.7M to Saskatchewan's GDP (Table 6).⁷²

TABLE 6

Activity Resulting from Ag-West Funding (\$000 / 1989-2002)

	Sources of Investment Ag-West	Other	Direct Impact Research Outlays	Product Sales	Output Effect GDP
1989	872	872	1,744	-	1,962
1990	780	664	1,444	-	1,625
1991	0	62	62	-	140
1992	763	664	1,427	1,330	3,102
1993	1,575	2,215	3,790	4,942	9,825
1994	359	1,235	1,594	9,662	12,664
1995	1,064	1,550	2,614	15,402	20,268
1996	928	5,145	6,073	13,872	22,439
1997	850	7,495	8,345	32,067	45,464
1998	609	8,017	8,626	36,962	51,287
1999	1,000	9,092	10,092	49,689	67,253
2000	176	9,427	9,603	47,710	64,478
2001	20	2,590	2,610	44,358	52,839
2002	270	3,490	3,860	59,572	71,706
2003*	100				
Totals	9,368	52,518	61,886	315,566	424,706

* To the end of March.

Source: Ryan & Smyth Facilitating Innovation in Agricultural Biotechnology: An Examination of the Ag-West Biotech Model, 1989-2004.

A simplified calculation of Saskatchewan's ROI based on the total public funding of AWT between 1989 and 2002 of \$13.5M can be compared with the (a) \$48.3M of additional private investment, (b) \$315.5M of newly developed product sales, and (c) the \$424.7M output effect on Saskatchewan's GDP.

$$14 \text{ year ROI (private investment)} = \frac{\$48.3 \text{ million} - \$13.5 \text{ million}}{\$13.5 \text{ million}} = 257.8\%$$

$$14 \text{ year ROI (new product sales)} = \frac{\$315.5 \text{ million} - \$13.5 \text{ million}}{\$13.5 \text{ million}} = 2237\%$$

$$14 \text{ year ROI (GDP contribution)} = \frac{\$424.7 \text{ million} - \$13.5 \text{ million}}{\$13.5 \text{ million}} = 3046\%$$

Note that the simplified ROI may be inflated or deflated based on proper measurement of all benefits and costs. By dividing the 14 year ROI by 14 we are able to estimate the average yearly nominal ROI for Saskatchewan.

$$\text{Avg/yr Return on Investment (private investment)} = \frac{(\$48.3 \text{ million} - \$13.5 \text{ million}) \div 14 \text{ years}}{\$13.5 \text{ million}} = 18.4\%$$

$$\text{Avg/yr Return on Investment (new product sales)} = \frac{(\$315.5 \text{ million} - \$13.5 \text{ million}) \div 14 \text{ years}}{\$13.5 \text{ million}} = 159.8\%$$

$$\text{Avg/yr Return on Investment (GDP contribution)} = \frac{(\$424.7 \text{ million} - \$13.5 \text{ million}) \div 14 \text{ years}}{\$13.5 \text{ million}} = 217.7\%$$

Another measurement used almost exclusively in public investment is the benefit-cost ratio.⁷³ The ratio is calculated by dividing the benefits of the project by the the cost of the project. In most benefit-cost analyses, the greater the ratio then the better the project.

$$\text{Benefit-Cost Ratio (private investment)} = \frac{\$48.3 \text{ million}}{\$13.5 \text{ million}} = 3.6$$

$$\text{Benefit-Cost Ratio (new product sales)} = \frac{\$315.5 \text{ million}}{\$13.5 \text{ million}} = 23.4$$

$$\text{Benefit-Cost Ratio (GDP contribution)} = \frac{\$424.7 \text{ million}}{\$13.5 \text{ million}} = 31.5$$

The internal rate of return is the interest rate (IRR) which is a financial measurement primarily used for evaluating investments, capital acquisitions, project proposals, and programs. IRR is calculated so that the net present value of all cash flows equal to zero. The measurement is generally interpreted so that the higher the IRR the more preferred the investment, project, or program.

Internal Rate of Return (private investment) =49.8%
 Internal Rate of Return (new product sales) =84.3%
 Internal Rate of Return (GDP contribution) =153.5%

By comparing AWT’s ROIs to other investment ROIs we are able to assess how well the government decision to investment in AWT performed.⁷⁴ Numerous studies have been conducted calculating the rates of return on investment in agricultural research. These rates have varied greatly depending on the characteristics of the study, the analysts, and the nature of research evaluated. By using the pattern of rates of returns across 292 publications and 1,886 observations we should get a good comparison which to measure Saskatchewan’s investment into AWT (Figure 7).

When measuring investment choice it is always important to measure rates of return with and without the effects of inflation. Real rates of return strip out the inflationary effect and use a discount rate to lessen the rate of return over time. Using the Saskatchewan’s Consumer Price Index and the average weighted yield on long term provincial bonds between 1989 and 2002, recalculation AWT’s real IRR (GDP) and the real IRR (Product Sales) still exceed the average, with the exception of the IRR (Product Sales) discounted by the average weighted long term provincial bonds (Table 7).

Comparing AWT’s calculated rates of returns on GDP and Product Sales to other rates of return organized

by commodity orientation, research type, and country demonstrates that Saskatchewan’s investment exceeds the median (Figure 8; Table 8; Table 9; Table 10).

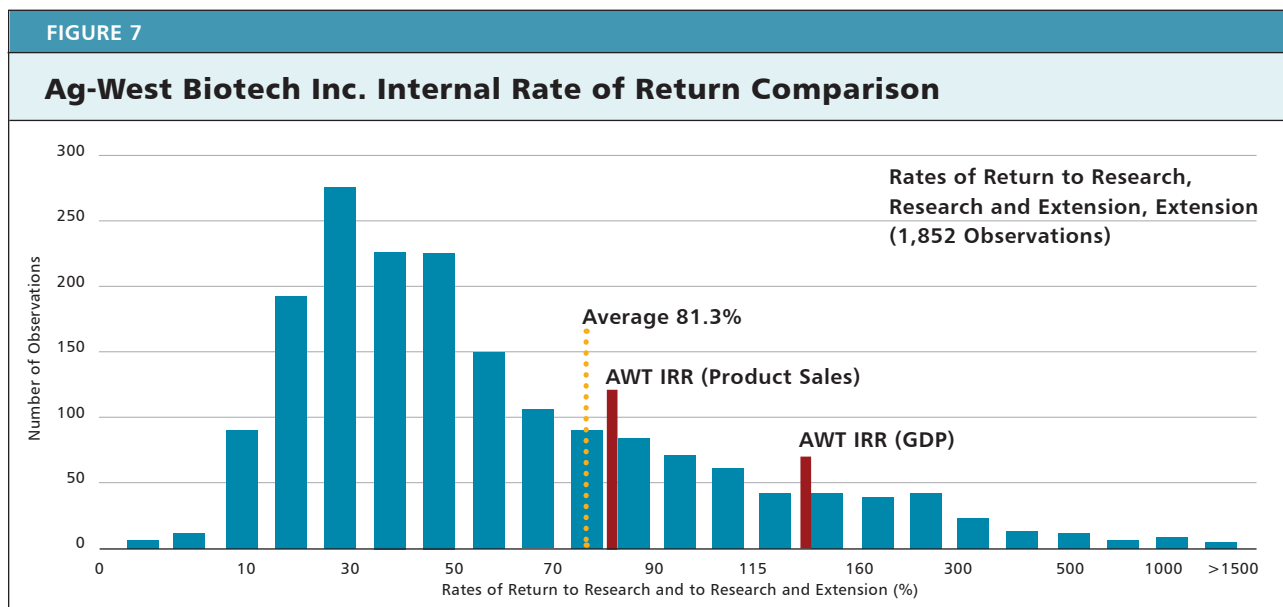
While a more comprehensive calculation of the ROI and IRR could be used to obtain a precise ROI for AWT, it appears that across a variety of measurements compared to a variety of return categories the rate of return for Saskatchewan over the 14 year period was exceptional (Table 11).

TABLE 7

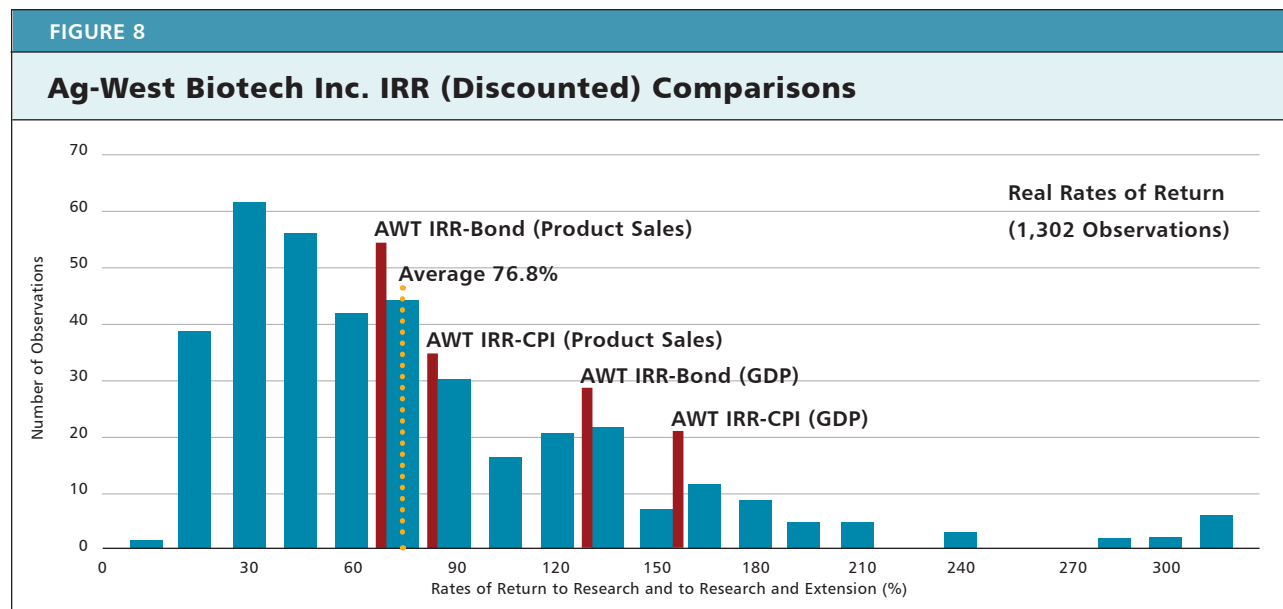
Saskatchewan CPI (All Goods Year/Year) (2002 Base Dollars)

Year	SK-CPI (All Goods) Yr./Yr. (2002 Base)	Other Bonds Provincial
1989	5.1%	10.49%
1990	4.8%	11.59%
1991	5.6%	10.54%
1992	1.4%	9.48%
1993	1.9%	8.63%
1994	0.1%	9.27%
1995	2.2%	8.85%
1996	1.5%	7.96%
1997	1.7%	6.77%
1998	1.0%	5.93%
1999	1.8%	6.19%
2000	2.7%	6.48%
2001	2.5%	6.35%
2002	2.2%	6.13%

Source: <http://www.stats.gov.sk.ca/stats/cpi/cpihistoricaltables.pdf>.



Source: Alston, Julian et.al. A Meta-Analysis of Rates of Return to Agricultural R&D Ex Pede Herculem?.



Source: Alston, Julian *et.al.* A Meta-Analysis of Rates of Return to Agricultural R&D Ex Pede Herculem?.

TABLE 8

Rates of Return by Commodity Orientation

Commodity Orientation	Number of Observations	Rate of Return				
		Mean	Mode	Median	Minimum	Maximun
	(Count)			(Percentage)		
Multicommodity ^a	436	80.3 (110.7)	58.0	47.1	-1.0	1,219.0
All Agriculture	342	75.7 (110.9)	58.0	44.0	-1.0	1,219.0
Crops and Livestock	80	106.3 (115.5)	45.0	59.0	17.0	562.0
Unspecified ^b	14	42.1 (19.8)	16.4	35.9	16.4	69.2
Field Crops ^c	916	74.3 (130.4)	40.0	43.6	-100.0	1,720.0
Maize	170	134.5 (271.2)	29.0	47.3	-100.0	1,720.0
Wheat	155	50.4 (39.4)	23.0	40.0	-47.5	290.0
Rice	81	75.0 (75.8)	37.0	51.3	11.4	466.0
Livestock ^d	233	120.7 (481.1)	14.0	53.0	2.5	5,645.0
Tree Crops ^e	108	87.6 (216.4)	20.0	33.3	1.4	1,736.0
Resources ^f	78	37.6 (66.0)	7.0	16.5	0.0	457.0
Forestry	60	42.1 (73.0)	7.0	13.6	0.0	457.0
All Studies	1,772	81.2 (216.1)	46.0	44.0	-100.0	5,645.0

Source: Alston, Julian *et.al.* A Meta-Analysis of Rates of Return to Agricultural R&D Ex Pede Herculem?.

Notes: See notes to Table 12. Standard deviations are given in parentheses. Sample excludes two extreme outliers and includes only returns to research only and combined research and extension, so that the maximum sample size is 1,772. In some instances further observations were lost owing to incomplete information on the specific characteristics of interest.

a. Includes reserach identified as "all agriculture" or "crops and livestock," as well as "unspecified."

b. Includes estimates that did not explicitly identify the commodity focus of the research.

c. Includes all crops, barley, beans,cassava,sugar cane,groundnuts,maize,millet,other crops, pigeon pea or chickpea, potato, rice, sesame, sorghum, and wheat.

d. Includes beef, swine, poultry, sheep and goats, all livestock, sairy, other livestock, pasture, dairy and beef.

e. Includes "other tree" and "fruit and nuts."

f. Includes fishery and forestry.

TABLE 9

Ranges of Rates of Return						
Sample	Number of Observations	Rate of Return				
		Mean	Mode	Median	Minimum	Maximum
	(Count)			(Percentage)		
Full Sample ^a						
Research Only	80	99.6	46.0	48.0	-7.4	5,645
Extension Only	628	84.6	47.0	62.9	0.0	636
Research and Extension	1,852	47.6	28.0	37.0	-100.0	430
All Observations	916	81.3	40.0	44.3	-100.0	5,645
Regression Sample ^b						
Research Only	598	79.6	26.0	49.0	-7.4	910
Extension Only	18	80.1	91.0	58.4	1.3	350
Research and Extension	512	46.6	28.0	36.0	-100.0	430
All Observations	1,128	64.6	28.0	42.0	-100.0	910

a. The original full sample included 292 publications reporting 1,886 observations. Of these, 9 publications were dropped because rather than specific rates of return they reported results such as ">100 percent" or "<0." As a result of these exclusions, 32 observations were lost. Of the remaining 1,854, two observations were dropped as extreme (and influential) outliers. These two estimates were 724,323 percent and 455,290 percent per year.

b. Excludes outliers and observations that could not be used in the regression owing to incomplete information on explanatory variables. See text.

TABLE 10

Rate of Return by Geographical Region of Research						
Geographical Region	Number of Estimates	Rate of Return				
		Mean	Mode	Median	Minimum	Maximum
	(Count)			(Percentage)		
Developed Countries	990	98.2 (278.1)	19.0	46.0	-14.9	5,645
North America ^a	740	102.4 (306.9)	22.0	46.5	-14.9	5,645
Europe	85	93.9 (152.0)	19.0	62.2	0.0	1,219
Australasia ^b	154	83.7 (177.9)	20.0	28.7	-1.3	1,736
Other Dev. Countries ^c	11	55.6 (36.1)	22.2	37.4	22.2	125
Developing Countries	683	60.1 (84.1)	46.0	43.0	-100.0	1,490
Africa	188	49.6 (113.0)	10.9	34.3	-100.0	1,490
Asia & Pacific	222	78.1 (53.2)	49.0	49.5	6.0	1,000
Latin America and Carib.	262	53.2 (39.3)	46.0	42.9	3.0	325
West Asia & N. Africa	11	44.2 (19.6)	28.0	36.0	28.0	80
Multinational	74	58.8 (98.3)	32.0	34.0	-47.5	677
International Agricultural Research Center	62	77.8 (188.6)	26.0	40.0	9.9	1,490

Notes: Standard deviations are given in parentheses. Sample excludes two extreme outliers and includes only returns to research only and combined research and extension, so that the maximum sample size is 1,772. In some instances further observations were lost owing to incomplete information on the specific characteristics of interest.

a. United States and Canada.

b. Australia and New Zealand

c. Japan and Israel.

TABLE 11				
ROI-GDP, ROI-Investment, ROI-Product Sales (1989-2002)				
Invested	ROI ROI Calculation	ROI (GDP)	ROI (Product Sales)	(Private Investment)
\$13.5M Invested	14 Yr. ROI	3046%	2237%	257.8%
	Avg./Yr. ROI	217.7%	159.8%	18.4%
	Benefit-Cost Ratio	31.5	23.4	3.6
	IRR (Nominal)	153.5%	84.3%	49.8%
	IRR (CPI)*	151.1%	83.3%	48.8%
	IRR (Bond)**	133.1%	72.5%	41.7%

* Discounted by Saskatchewan CPI Year over Year (All goods base year 2002) 1989-2002.

** Discounted by Annual Average Weighted Provincial Long Term Bonds 1989-2002.

ADDITIONAL GAINS TO CONSIDER

- Networking, Knowledge Spillovers, and Tourism:** Between 1996 and 2003 AWT hosted 175 tours (with delegates from around the globe) and was involved in over 200 conferences worldwide. In addition, AWT hosted the annual Agricultural Biotechnology International Conference (a premier conference on agricultural biotechnology) in 1996, 1998, and 2002. The conferences alone generated direct local tourism dollars for Saskatchewan of approximately \$3M.⁷⁵
- Decrease in Regulatory complexity:** AWT aided Saskatchewan's biotechnology industry with public policy and industry information. The 1997 Fourth Report on the Canadian Biotechnology Industry by Ernst & Young surveyed biotechnology companies in Canada. The survey concluded that the greatest challenge for the biotechnology sector was Canada's complex regulatory system which impedes commercialization, estimating that regulatory delays decreased rates of return between 3% and 6% per year.⁷⁶
- International Leadership:** In 2009, the OECD released The Bioeconomy to 2030: Designing a Policy Agenda that identified that "the most serious challenges to world economies and societies over the next decades" include food, water, energy, and healthcare. The conclusions of the report highlight the very same work that Saskatchewan's AWT began twenty years earlier, in 1989. They include: (a) building a foundation for long-term development of the bioeconomy by creating and maintaining markets

for sustainable products and, funding basic and applied research, and investing in multi-purpose infrastructure and education; (b) reducing barriers to biotechnology innovation such as aiding in high research costs and reducing regulatory barriers; (c) promoting the integration of biotechnology research across commercial applications by supporting integration through coordinating expertise between those responsible for agriculture, education, environment, natural resources and research; and (d) creating a dialogue between government, citizens, and researchers.⁷⁷ With the creation of Ag-West Bio in 2004, the economic benefits and overall rate of return continue to multiply exponentially.

CONCLUSION

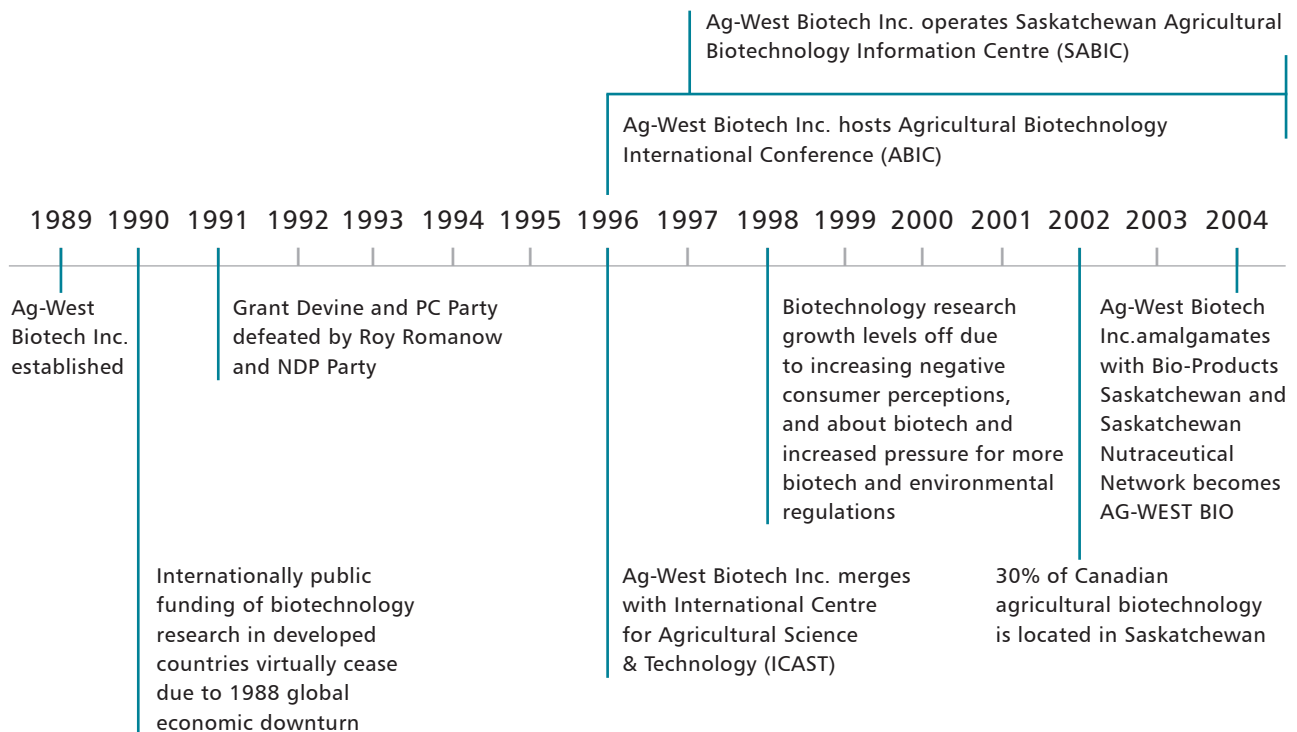
“We are celebrating five outstanding individuals this year, and the tremendous and lasting contributions they have made to the landscape of Canadian Agriculture. Just as our industry is diverse, so are this year’s inductees – representing all the segments that weave together support and sustain our progressive and innovative industry. Through their leadership and vision, they have contributed to advancing agriculture over the last 100 years – from primary research to marketing to organizing commodity groups and educating young agricultural leaders.”⁷⁸

- Herb McLane, President of the Canadian Agricultural Hall of Fame Association, 2015

Ag-West Biotech Inc. was created and given a specific mandate to provide leadership and assistance to Saskatchewan’s Ag-biotech sector through assisting Saskatchewan companies to grow and aid them in the commercialization of new biotechnologies. With a retrospective view on history, it is clear Ag-West Biotech Inc. fulfilled its mission and provided Saskatchewan a phenomenal rate of return on its investment; the returns still continue today by its successor Ag-West Bio (Figure 9).

The decision made at a single moment in time, back in 1989, by the Saskatchewan government during one of the worst economic downturns in the provinces history placed Saskatchewan on the path of becoming a world leader in agricultural biotechnology and a leader in agricultural innovation and technology.⁷⁹ Capitalizing on Saskatchewan’s rich agricultural history, the creation of Ag-West Biotech Inc. is a remarkable story of risk, reward, and forward thinking in Saskatchewan public choice.

Figure 9
Ag-West Biotech Inc. Timeline (1989-2004)



23. *Ibid.*
24. Green, Christopher. *The Industrial Economics of Biotechnology*. Springer US. Kluwer Academic Publishers. 1998. Pg 345.
25. *Ibid.*
26. A public good is nonrivalrous and nonexcludable. Non-rivalrous means that the good is equally available to all and non-excludable makes it impossible exclude from use by those who do not pay for it.
27. Green, Christopher. *The Industrial Economics of Biotechnology*. Springer US. Kluwer Academic Publishers. 1998. Pg 345.
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29. *Ibid.*, Pg 14.
30. Duca, John V. and Mine K. Yücel. Edited. "Science & Cents Exploring the Economics of Biotechnology". Federal Reserve Bank of Dallas. April 19, 2002. Pg 10. <https://core.ac.uk/download/pdf/7359332.pdf> (accessed June 6, 2017).
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33. Ag-West Bio. "History Ag-West Bio: A catalyst for Saskatchewan's bioeconomy". <http://www.agwest.sk.ca/about/history.html> (accessed June 6, 2017).
34. *Ibid.*, "About".
35. Mitura Economic Research Inc. "The Bio-Products Industry A SAC Inc. State of the Industry Fact Sheet". Saskatchewan Agrivision Corporation. June 2002. <http://agrivision.usask.ca/pdf/factsheets/bioproducts.pdf> (accessed June 6, 2017).
36. Participants to the demonstration laboratory were invited to extract DNA, prepare a blueprint of DNA using gel electrophoresis, as well as observe and discuss applications of biotechnology.
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39. Mitura Economic Research Inc. "The Bio-Products Industry A SAC Inc. State of the Industry Fact Sheet". Saskatchewan Agrivision Corporation. June 2002. <http://agrivision.usask.ca/pdf/factsheets/bioproducts.pdf> (accessed June 6, 2017).
40. *Ibid.*
41. *Ibid.*
42. *Ibid.*
43. A synchrotron can be used to probe matter and analyze a host of physical, chemical, geological and biological processes. Data provided by the Synchrotron can be used to help design new drugs, develop more effective motor oils, create more powerful computer chips, safer medical implants, etc.
44. Canadian Light Source. *Synchrotron Science Classroom Materials Background Material*. 2012. Pg 2-3. [http://www.lightsource.ca/ckfinder/userfiles/files/SSCR2013Jul23-Formatted-for-Web%20\(1\).pdf](http://www.lightsource.ca/ckfinder/userfiles/files/SSCR2013Jul23-Formatted-for-Web%20(1).pdf) (accessed June 6, 2017).
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57. *Ibid.*
58. This account records the funding to support research into the development of new agricultural technology and to facilitate diversification and value-added opportunities in the agri-food industry. The program provides financial assistance for research and development programs and projects.
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60. Saskatchewan. Ministry of Finance. *Public Accounts 1994-95*. Volume 2. October 1995. Pg 40.
61. Saskatchewan. Ministry of Finance. *Public Accounts 1995-96*. Volume 2. October 1996. Pg 40.
62. Saskatchewan. Ministry of Finance. *Public Accounts 1996-97*. Volume 2. October 1997. Pg 39.
63. Saskatchewan. Ministry of Finance. *Public Accounts 1997-98*. Volume 2. October 1998. Pg 39.
64. Saskatchewan. Ministry of Finance. *Public Accounts 1998-99*. Volume 2. October 1999. Pg 40.
65. Saskatchewan. Ministry of Finance. *Public Accounts 1999-2000*. Volume 2. October 2000. Pg 40.
66. Saskatchewan. Ministry of Finance. *Public Accounts 2000-2001*. Volume 2. October 2001. Pg 41.
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68. Ryan. Camille D. and Stuart J. Smyth. "Facilitating Innovation in Agricultural Biotechnology: An Examination of the Ag-West Biotech Model, 1989-2004". *AgBioForum* 2010, 13(2) Pg 186. <http://www.agbioforum.org/v13n2/v13n2a09-smyth.htm> (accessed June 6, 2017).
69. Leverage ratio is a financial measurement that measures how much capital comes in the form of debt (loans) and assesses the ability of a company to meet financial obligations.
70. Ryan. Camille D. and Stuart J. Smyth. "Facilitating Innovation in Agricultural Biotechnology: An Examination of the Ag-West Biotech Model, 1989-2004". *AgBioForum* 2010, 13(2) Pg 188. <http://www.agbioforum.org/v13n2/v13n2a09-smyth.htm> (accessed June 6, 2017).
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76. *Ibid.*, Pg 191.
77. Organisation for Economic Co-operation and Development. OECD International Futures Project. "The Bioeconomy to 2030: Designing a Policy Agenda Main findings and policy conclusions". May 2009. Pg 6-7. <https://www.oecd.org/futures/long-termtechnologicalsocietalchallenges/42837897.pdf> (accessed June 6, 2017).
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