Innovative Agbioscience in Indiana: A Baseline Assessment

Prepared by:

Battelle
Technology Partnership Practice

Submitted to:

AgriNovus Indiana of the
Central Indiana Corporate Partnership, Inc.

October 2014

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Executive Summary

Indiana is undeniably a national leader in agricultural production of both crops and livestock. The state's 60,000 farms cover 19.4 million acres of land and generated $11.2 billion in farm gate sales in 2012—ranking the state 10th in the nation in agricultural production value, even though it ranks only 18th in total farmland. That same year, Indiana agriculture exports reached a record $4.7 billion. The broader food and agriculture sector contributes $16 billion to Indiana's Gross State Product and employs 19 percent of the Hoosier workforce. Agriculture in Indiana clearly represents a high-performance economic sector in terms of productivity and impact.

The impressive productivity of Indiana agriculture results from the hard work of Hoosier farmers, but also stems from the application of advanced agricultural practices and technologies. Modern agbioscience innovations, developed at major land-grant universities like Purdue University, at U.S. Department of Agriculture research centers, and at major agbioscience corporations, drive consistent improvements in yields and farming output. Indeed, there is a well-established agbioscience and agricultural technology ecosystem in the United States that provides the know-how, technologies, and processes needed to keep Indiana agriculture at the forefront of modern agricultural practice.

This report examines the state of this agbioscience and agricultural technology ecosystem in Indiana, providing the Central Indiana Corporate Partnership (CICP) with a detailed examination of key agbioscience innovation drivers in Indiana. Performed by the Battelle Technology Partnership Practice, this detailed analysis reveals the current "state-of-the-state" in Indiana's agricultural sciences and associated technological development (collectively termed "agbioscience"). These advancements occur across the entire value-chain—from the R&D to produce advanced inputs to agriculture (such as high performance seed, crop protection products, livestock veterinary health technologies, and high-tech precision farming equipment) through to the downstream value-added processing of farm output into processed foods, health products, fibers and industrial products. Advancements also occur in Indiana through basic scientific inquiry in plant sciences, animal science, agronomy, entomology and associated disciplines (especially at Purdue University) and through a concerted program of applied research and field testing performed by industry and Purdue's agricultural experiment station system. As new technologies and practices emerge from Indiana's agbioscience innovation ecosystem, there is also a long-standing service in the state dedicated to diffusing knowledge and best practices to farmers—the Purdue University Extension Service—with this diffusion further supplemented by advisors from industry and consulting service providers.

This study is the first of its kind for Indiana. It sets forth to determine the current status of agbioscience innovation and R&D in the state, and to identify the key industry and non-profit sector organizations driving modern agbioscience innovation in Indiana.

Indiana: Building Upon a Base of Life Sciences Strength

At its heart, the agbiosciences are part of the larger life sciences sector—a sector that encompasses a diverse array of industries, including drugs and pharmaceuticals, medical devices and equipment, and biotechnology. Indiana enjoys a signature position in life sciences, a position well-documented in national studies that examine the comparative performance of U.S. states. Battelle's recent report for the Biotechnology Industry Organization (BIO) confirms the leadership of Indiana in life sciences, noting that it is among only two other states (Illinois and California) in having three out of five national life science sectors be both "large and specialized."

Indiana enjoys a well-proven and differentiated position in life sciences—strong in agbiosciences, human and veterinary biomedical sciences, and medical devices and equipment. Indiana is not dependent on the fortunes of any individual life science sector, and instead has the enviable position of being able to build upon the perspectives, synergies, and multidisciplinary opportunities presented by having a robust base of multiple life science fields.

Agbiosciences: A Signature Economic Development Opportunity

Whenever very large-scale market needs meet emerging technologies and production capabilities there are substantial economic development opportunities. This is the case with modern agbiosciences. Agricultural advancements will continue to provide potential market-based solutions to many of the globe's most pressing challenges over the next several decades:

- How do we meet the nutrition needs of a rapidly expanding global population, and how do we do so without degrading our finite natural resource base (arable land and water)?
- How do we provide diets that sustain and strengthen health, allowing the world's population to be productive?
- How can we expand the use of renewable and sustainable resources and move away from economies dependent on non-renewable resources and the generation of waste?
- How do we address the challenges of global climate effects, water resource depletion, pollution and the proliferation of toxins and contaminants from human activity?
- How do we create enhanced economic opportunities and generate sustainable economic development?

The work of industry, university, and government scientists and engineers in the agbiosciences promises solutions to these major food security, nutrition, health, sustainable industry, and environmental needs. Each of these needs represents a potential multibillion dollar market, and the states and regions that are well-resourced in agbioscience innovation assets are those best-positioned to grow their economies to leverage these large-scale economic opportunities.

Establishing a Baseline for Indiana's Innovative Food and Agriculture Sector

Recognizing the economic potential associated with the agbiosciences, CICP sponsored the formation of the Indiana Food and Agriculture Innovation Initiative (IFAII) to advance collaborations across the agricultural value-chain and to facilitate the growth of agbioscience innovation in the state.

A first step in undertaking practical and strategic efforts to enhance agbioscience-based economic development is the establishment of a knowledge base regarding the current status of Indiana agbioscience R&D and innovation activity. Battelle has performed a range of analyses to reveal the fundamental structure of agbioscience assets in the state, and to elucidate the specific companies that are active in agriculture innovation across the value-chain. Specific tasks included

- a review of published R&D output through application of advanced cluster analysis techniques to identify specific clusters of academic and corporate R&D activity;
- an in-depth assessment of agbioscience and associated patents assigned to Indiana inventors;
- an examination of federal SBIR grant awards and venture financing records to identify early stage companies; and
- identifying in close collaboration with BioCrossroads and IFAII the individual companies in Indiana classified within agbioscience subsectors likely to contain significant innovation activity.

In addition to gathering quantitative data on R&D and developing a database of Indiana innovative agbioscience companies, Battelle undertook a series of interviews with innovative companies in the state and has provided narrative vignettes throughout to illustrate the broad range of agbioscience innovation activity occurring in Indiana.

Agbioscience Research Enterprise in Indiana

Purdue University is the key engine to academic agbioscience R&D in Indiana—performing fully 99 percent of university-based agbioscience research in the state[1]. Notably, Purdue has been a consistently strong performer in building its agbioscience research volume, with total agbioscience research expenditures increasing 33.5 percent between 2003 and 2012—rising from $88.4 million in 2003 to $118 million in 2012.

In core agbioscience disciplines, Indiana performs very well in research output, as measured by publications. Evaluated objectively using location quotients[2] (LQs), Indiana is specialized in academic publishing in Plant Sciences (LQ 1.26), Veterinary Medicine and Animal Health (1.25), Agriculture and Agronomy (1.22), Animal and Plant Science (1.68), Animal Sciences (1.15), Agricultural Chemistry (1.10), and Entomology and Pest Control (1.08). Only in Food Science and Nutrition does Indiana have a lower than average concentration, with an LQ of 0.92.

Taking a deeper dive into Indiana agbioscience research strengths, Battelle deployed OmniViz™ and its pattern recognition algorithms to cluster research fields into grouped strength areas. From 2009 through June 2014, a total of 3,169 agbioscience publications were analyzed. The analysis identified 38 distinct clusters of agbioscience research publishing activity in Indiana, ranging from a high of 352 papers in "water and soil" to the smallest cluster with just six records in "wood materials engineering". The full OmniViz™ analysis suggest that key themes in agbioscience research in Indiana center on:

- Veterinary medicine, with a companion animal emphasis;
- Livestock nutrition and feed;
- Basic and applied plant sciences, primarily focused on commodity crops; and
- Water, soils and ecological/eco-system resources.

It is important to note that a number of research areas did not stand out in the publications analysis. Areas such as food science and human nutrition, biomass conversion and biobased fuels and chemicals, and agricultural engineering did not produce clusters in the OmniViz™ analysis.

Patent data also comprise an important measure of agbioscience innovation activity. Battelle analyzed patent data for 2009 through 2013 for patents that were invented by Indiana inventors or assigned to an Indiana headquartered company. This broad analysis identified 823 issued patents spanning the agricultural, animal health and husbandry, and food processing and preparation equipment space. It is evident from these data that the large plant science-oriented companies (Dow AgroSciences, DuPont Pioneer and Monsanto) are the dominant generators of Indiana-related patents—with these three companies having 654 (or 79 percent) of the patents identified.

Agbioscience Employment in Indiana

The total agbioscience industry (including farm production) in Indiana employed 133,765 personnel across the full value-chain in 2012 (Table ES-1). Not including Primary Production (farming), the remaining segments of the agbioscience industry employed 68,849 (51.5 percent of total value-chain employment).

[1] Source: National Science Foundation
[2] Location Quotients measure relative concentration versus the nation. A location quotient of 1.0 means that the reference geography has the same concentration in a discipline as expected given national averages. A location quotient greater than 1.0 indicates a relatively higher concentration, whereas a location quotient lower than 1.0 indicates a relatively lower than expected volume of publishing.

Table ES-1. Indiana Agbioscience Employment, Establishments, Wages and Specialization

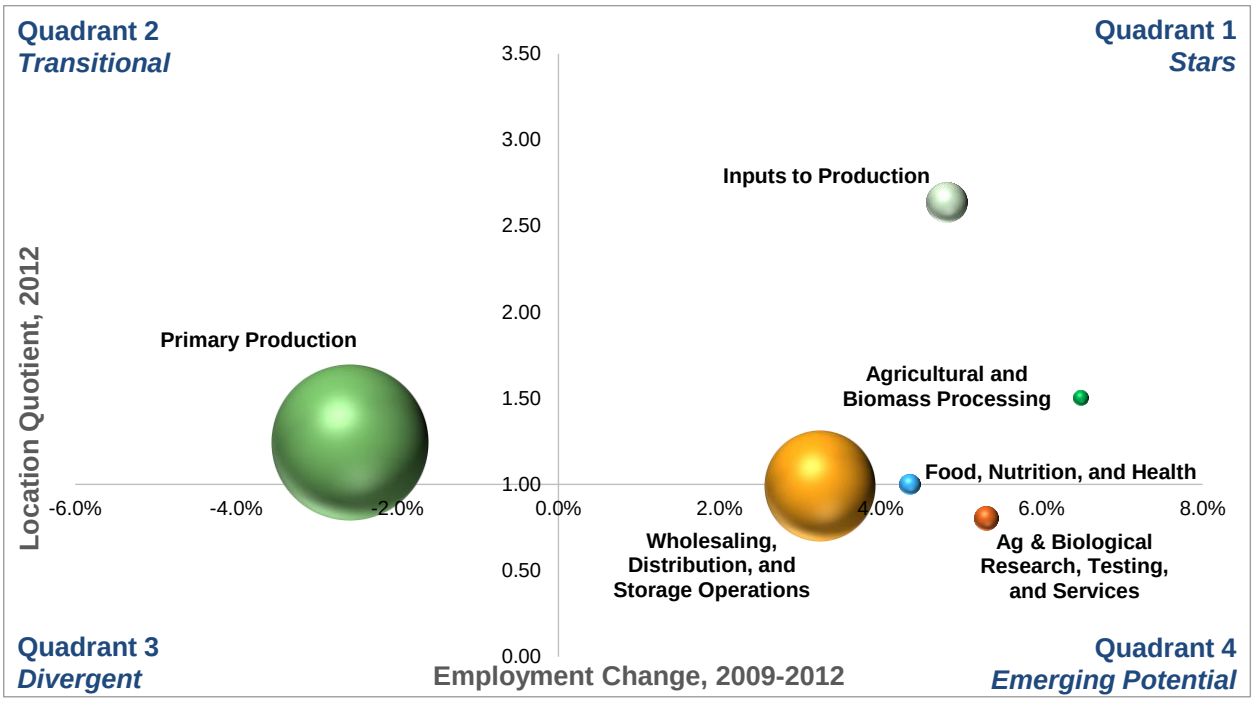
Agbioscience Segment	2012 Metrics				Recent Employment Performance				
	Estabs.	Employ.	Avg. Wage	Special-ization	Change Through Recession, 2003-2009	Change Post Recession, 2009-2012	Total Change, 2003-2012	U.S. Post Recession Change	U.S. Total Period Change
Ag & Biological Research, Testing, and Services	759	7,826	$36,025	0.80	12.8%	5.3%	18.8%	4.1%	22.6%
Agricultural & Biomass Processing	139	4,904	$54,194	**1.51**	4.8%	6.5%	11.7%	0.3%	-15.7%
Food, Nutrition, & Health	602	36,009	$39,558	0.99	7.5%	3.3%	11.0%	1.2%	-2.4%
Inputs to Production	798	13,341	$65,780	**2.64**	4.3%	4.8%	9.3%	-29.9%	-32.9%
Primary Production	60,256	64,916	$32,330*	0.97	-1.6%	0.1%	-1.5%	0.6%	-1.7%
Wholesaling, Distribution, and Storage Operations	384	6,768	$43,495	1.00	7.8%	4.4%	12.5%	3.5%	9.4%
Total Agbioscience Industry	62,938	133,765	$43,430*	1.04	2.7%	2.1%	4.9%	-0.5%	-2.1%

Source: Battelle analysis of Bureau of Labor Statistics, QCEW data from IMPLAN, farm proprietor employment data from the Bureau of Economic Analysis, and farm proprietor establishment data from USDA NASS.
* Average wage estimate for corporate workers only.

Two of the agbioscience subsectors stand out as specializations for Indiana (as defined by location quotient or LQ). Inputs to Production has an LQ of 2.64, indicating that there is a 1.64 times higher level of employment in this sector in Indiana than would be expected given national averages. The other specialized sector is Agricultural and Biomass Processing with an LQ of 1.51. The other subsectors are at or close to national normative levels of employment concentration, except for the Agricultural and Biological Research, Testing, and Services sector, which is comparatively less specialized, only having an LQ of 0.80 (or 80 percent of the level of employment expected given national normative levels).

Inputs to Production is clearly a highly important agbiosciences subsector for Indiana. Highly concentrated and employing more than 13,000 workers, this subsector also provides high comparative levels of wages, with an average wage of $65,780—significantly higher than the average wage level in Indiana (which in 2012 stood at $41,356). The other specialized sector of Agricultural and Biomass Processing also demonstrates high wage levels, with an average wage of $54,194.

An important finding is that ***in all cases (other than Primary Production) Indiana has seen employment grow between 2003–2012.*** Post-recession (2009–2012) the agbioscience subsectors (again other than farming) have ranged in employment growth from 3.3 percent to 6.5 percent. Also, ***each of these subsectors has grown at a rate faster than the U.S. average in the post-recession time period.*** Figure ES-2 provides a graphical overview of Indiana's agbiosciences subsector performance in the post-recession period.



Source: Battelle analysis of Bureau of Labor Statistics, QCEW data from IMPLAN, farm proprietor employment data from the Bureau of Economic Analysis, and farm proprietor establishment data from USDA NASS.

Figure ES-1. Comparative Agbioscience Subsector Performance Post-Recession: 2009–2012
(Bubble size is proportionate to employment volume)

Indiana's Agbioscience Innovation Sectors with Greatest Opportunity

Considering the findings of all aspects of the Battelle research, it can be concluded that there are four main innovation sectors of opportunity for Indiana that leverage an existing industry base, R&D activity, and connect to significant future market opportunities. These four innovation sectors of opportunity include:

- Plant Science and Crop Protection
  - 19 innovative companies identified
  - 3,116 persons employed in Indiana
  - Very high patent generation (668 patents from 2009–2013)
  - Very high level of publishing activity (804 publications from 2009–June 2014)
- Value-Added Human Food and Nutrition Products
  - 30 innovative companies identified
  - 13,671 persons employed in Indiana
  - Moderate patent generation (35 patents from 2009–2013)
  - High level of publishing activity (396 publications from 2009–June 2014)
- Animal Health (Veterinary) and Nutrition Products
  - 9 innovative companies identified
  - 1,159 persons employed in Indiana

- Moderate patent generation (11 patents from 2009–2013)
- Very high level of publishing activity (662 publications from 2009–June 2014)

- Agricultural Production Equipment, Processing Equipment and Precision Agricultural Systems. Note: This is a combination of the Agricultural/Food Equipment and Production Technology Innovation Sector and the Precision Agriculture Sensing and Information Technology Innovation Sector. Due to the ever increasing role of Big Data and its impact on production and machinery technology, it would benefit Indiana to more tightly link these two innovation sectors, which together represent:
  - 27 innovative companies identified
  - 1,404 persons employed in Indiana
  - Moderate patent generation (25 patents from 2009–2013)
  - Moderate level of publishing activity (100 publications from 2009–June 2014)

Each of these four innovation sectors has significant potential for future growth and economic development in Indiana because they address large-scale global markets with significant projected growth rates. Driven by global population and wealth increases, the demand for agricultural inputs and outputs is well assured, and states such as Indiana that sustain and grow an innovative industry base in agbiosciences will be well positioned for economic growth. This growth will come through the development and production of technologies used in agriculture, in agricultural production itself, and in the downstream processing of agricultural commodities into value-added products.

Advancing Innovative Agbiosciences in Indiana

It is clear that Indiana is operating from a position of strength in agbiosciences, both in terms of its innovative corporate sector and the R&D base in academe, primarily concentrated within Purdue University. This position, however, can be strengthened further through collaborative actions and by policies and strategies purposefully designed to enhance the Indiana operating environment and innovation ecosystem in agbioscience. Chief among these are discussed in Table ES-2.

Table ES-2: Preliminary Challenge Areas for Agbioscience Development and Potential Strategies and Actions for Further Consideration.

Challenge Area	Potential Strategy and Action Considerations
Develop collaborations within innovation sectors	• Form key stakeholder subcommittees for each of the innovation sector opportunity areas: 1) plant science and crop protection; 2) value-added human food and nutrition products; 3) animal health and nutrition products, and 4) agricultural production equipment, processing equipment and precision agricultural systems. • Develop university/industry collaboration initiatives in targeted leading-edge areas where the state has assets but does not yet have a sufficiently robust position (such as precision agriculture). • Conduct frequent seminars and colloquia within Indiana related to each of the innovation sectors to encourage dialog on shared needs, emerging technology areas and opportunities, etc. • Encourage partnerships between Indiana companies that enhance global competitive advantage, such as the recent announcement by Elanco and Dow AgroSciences of a strategic R&D agreement that will focus on developing integrated solutions to enable livestock producers to increase meat and milk production to meet the demands of the growing global population.

Challenge Area	Potential Strategy and Action Considerations
	• Look for opportunities to connect Indiana's biomedical expertise to relevant agbioscience-based opportunities in functional foods, advanced nutrition and feed products, and veterinary medicine.
Improve the visibility of Indiana as a leading hub for agbioscience innovation	• Develop a brand for IFAII and launch the brand inside Indiana and externally. • Develop IFAII website to include brief listings of companies by key cluster/innovation sectors. • Attend major agbioscience/cluster-oriented conferences and events to promote Indiana agbiosciences. • Develop strategic relationships with international clusters focused in similar areas (a "cluster of clusters" approach).
Fill gaps in the innovation value-chain	• Perform interviews with the innovative agbioscience companies in the Battelle-developed database to identify major assets, resources, services, ingredients or components that these companies are having to source from out-of-state. • Develop a prioritized list of business recruitment candidates based on a review of individual and shared needs of Indiana innovative agbioscience companies. • Quantify volumes of agricultural commodities leaving Indiana in unprocessed form for opportunities to add further value in-state.
Facilitate the commercialization of new agbioscience innovations	• Perform outreach to existing agbioscience-oriented venture funds and angel investor groups in the United States to introduce Indiana opportunities. • Consider development of a dedicated seed/pre-seed fund for early stage proof of concept funding for agbioscience commercializable innovations. • Facilitate entrepreneurial access to business development assistance and specialized infrastructure and resources available in the state. • Work with industry and R&D centers to identify innovations and technologies that represent opportunities for commercialization—either with existing businesses or as new entrepreneurial business ventures. • Examine needs for specialized product development, piloting, and scale-up facilities to support emerging companies. • Develop an "entrepreneurial farmers" network comprised of farmers who are willing to experiment with new crops that have the potential to meet the needs of downstream value-added processors in the state.
Connect to broader, Midwest-regional agbioscience assets and initiatives	• Consider opportunities to pursue a broader Midwest agbioscience initiative leveraging assets and institutions in a multi-state region comprising states adjacent to Indiana (placing Indiana at its' heart). • Examine opportunities for collaborations with major land-grant universities within the broader region to add expertise in areas that are complementary to existing Purdue capabilities.
Ensure adequate supply of a talented workforce	• Solicit input from industry regarding challenges in recruiting skilled personnel and facilitate discussions with regional higher education institutions to develop specialized courses or skills-development programs to fill needs. • Encourage temporary visiting appointments between industry and academe to gain better insight as to respective needs and interests.

Challenge Area	Potential Strategy and Action Considerations
Ensure access to specialized advisory services	• Identify, through discussions with industry, specific external service requirements in relation to agbiosciences in areas such as regulatory affairs, food safety, bio-containment, aseptic processing, capital access, legal affairs, etc. • Form a network of in-state experts in key areas and facilitate access to this network.

The above represent a tentative set of challenges and potential actions based on preliminary Battelle insights, but should be further tested and refined based on interviews or surveys conducted with innovative agbioscience stakeholder companies and institutions in Indiana and the input of the IFAII steering committee.

Conclusion

Indiana is among the leaders in the nation in life sciences, and agbiosciences represent an important element of Indiana's life science leadership. The full agbioscience value-chain is an important contributor to the health of the Indiana economy, providing over 133,000 jobs. Furthermore, it is a sector that is well-positioned for growth into the future because of the linkage between global grand challenges and potential agbioscience-based solutions.

Indiana benefits from a diversified and growing base of agbioscience R&D and associated innovation. In particular, Indiana has an opportunity to leverage existing assets to sustain growth and economic development across four primary innovation sectors: 1) plant science and crop protection; 2) value-added human food and nutrition products; 3) animal health and nutrition products; and 4) agricultural production equipment, processing equipment and precision agricultural systems. Each of these innovation drivers not only leverages R&D strengths within the state and existing industry presence, they also address very large-scale global market opportunities.

Chapter 1. Introduction

The Agbiosciences—a Significant Development Opportunity

For a state to invest significant effort and funds in advancing specific sectors, there has to be a strong rationale, particularly in terms of line-of-site to ongoing demand and economic growth associated with the sector into the future. The agbiosciences represent an applied area of life science knowledge and innovation—a life science subsector engaging research and development (R&D) to improve, protect, and expand primary agricultural production and the production of value-added products based on agricultural outputs.

The agbioscience sector is an interconnected value-chain of agricultural-related economic activity, generally structured as illustrated in Figure 1.

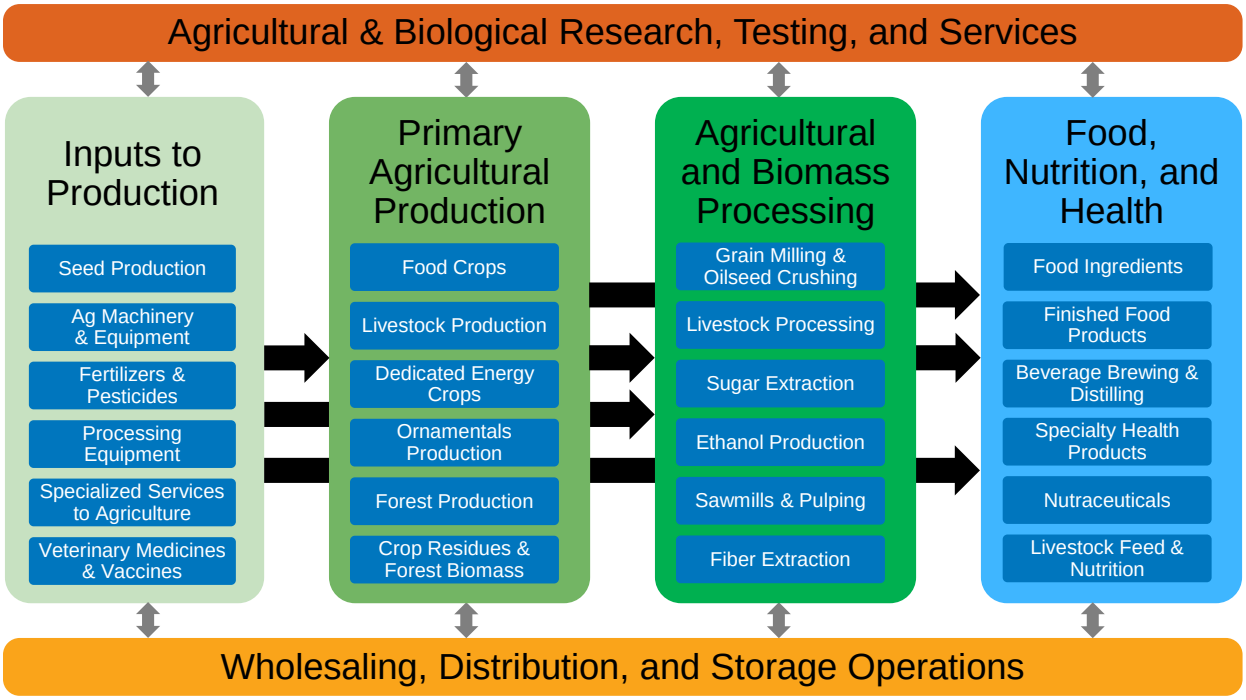


Figure 1. Key Components of the Agbioscience Value-Chain

Previous analysis performed by Battelle has illustrated the power of the agbiosciences to address many of the greatest and most pressing challenges facing humankind.[3] Indeed, Battelle concluded that:

> *There is no other arena of economic activity, or field of science and innovation, that so directly addresses human survival and quality of life, global economic development, and prospects for an environmentally sustainable future.*[4]

[3] See "Impact and Innovation: Agbioscience in the Southern United States." Battelle 2013. And "Power and Promise: Agbioscience in the North Central United States." Battelle 2011.
[4] "Power and Promise: Agbioscience in the North Central United States." Battelle 2011. Page 3.

In discussing agbiosciences across the North Central United States, including Indiana, Battelle described the global challenges that agbioscience advancements can address, or help address. The scale of these challenges is indicative of the high level of demand for potential agbioscience solutions:

> *On a global scale humankind's needs and challenges are daunting. Worldwide population is projected to increase from 7 billion in 2010 to 9.3 billion by 2030 (an increase of 2.3 billion, equivalent to doubling the entire current populations of China and India). To meet the rising demand for food (driven both by rising population and increasing income levels) it is anticipated that by 2030 we may actually need to double global food production, yet most cultivatable land is already in production. The inequity of global income levels and access to food across the planet already leads to debilitating levels of malnutrition, undernutrition and associated poor health for over 1 billion people. Meeting the demands of a growing population, for more and better food, and the demand for the fiber, fuels and materials required as inputs for economic growth, is made all the more difficult by the pressing need to do so while reducing environmental impacts and global climate change associated with human economic activity.*[5]

Agbiosciences represent a system of innovation that provides potential answers to many of our most pressing challenges:

- How do we meet the nutritional needs of a rapidly expanding global population, and how do we do so without degrading our finite agronomic land or causing further deforestation? How do we provide diets that sustain strength and health, allowing the world's population to be productive?
- How can we expand the use of renewable and sustainable resources and move away from economies dependent on non-renewable resources and generating waste?
- How do we address the challenges of global climate effects, water resource depletion, pollution and the proliferation of toxins and contaminants from human activity?
- How do we create enhanced economic opportunities and generate sustainable economic development?

The agbiosciences thus promise potential solutions to multiple major global grand-challenges in food security, nutrition and health, and sustainable industries development. As such, it is an area of scientific and technological development that addresses large-scale global market opportunities and has significant economic development potential attached to it.

Within the United States, and a leading agriculture and agbioscience state such as Indiana, the agbiosciences represent a dynamic, high-opportunity sector for economic development based on several key characteristics:

- Agbiosciences provide opportunities for business growth in the development of advanced products and technologies for use within the sector itself—technologies such as advanced seed, crop protection agents, precision agricultural equipment, and animal health and nutrition products.
- Agbiosciences leverage an established base of specialized U.S. university capabilities (especially within land-grant universities) and federal USDA lab capabilities. There is an extensive and highly evolved system for advancing agbioscience-based innovation in the United States.
- The United States is a global hub for major domestic agbioscience corporations (e.g., Monsanto, Dow AgroSciences, Cargill, Pioneer) and for R&D operations of major international agribusiness companies, such as BASF, Bayer Cropscience and Syngenta. And, the United States has a long-established track record in commercializing agbioscience research output both through established multinationals and a robust ecosystem of innovative small and mid-size agbioscience companies.

[5] Ibid. Page 3.

- Agbioscience-based economic development holds promise for enhancing the economic development of rural, small town and urban communities alike—with activities across a broad value-chain. While other advanced technology sectors have tended to grow in highly concentrated geographic clusters, agbiosciences build upon a geographically distributed production environment and are one of the few high-tech sectors able to have a robust impact on rural America.

Indiana—A Leading State in Life Sciences

Battelle's recently released report[6] for BIO shows the significant strength of Indiana's life science economy. Indiana is among the top tier of states in having three out of five national life science subsectors be both "large and specialized" (Table 1).

Table 1. Indiana's Life Science Subsector Performance (Battelle/BIO analysis)

	Agricultural Feedstocks and Chemicals	Drugs and Pharma-ceuticals	Medical Devices and Equipment	Research, Testing and Medical Laboratories	Bioscience Distribution
Degree of specialization (Location Quotient)[7]	2.94 Top Quartile	2.37 Top Quartile	2.48 Top Quartile	0.78 4th Quartile	1.19 2nd Quartile
Share of U.S. Employment	Top Quartile	Top Quartile	Top Quartile	3rd Quartile	3rd Quartile
Employment Change 2007-12	Top Quartile	4th Quartile	Top Quartile	Top Quartile	3rd Quartile

As Table 1 indicates, Indiana enjoys a strong position overall in the life science economy. Highlights include:

- Being one of only a dozen states to be specialized in three or more subsectors, and one of only three states (Indiana, Illinois, and California) to be both "large and specialized" in three or more subsectors (with large defined as having 5 percent or more of total U.S. subsector employment);
- One of only four states that are "large and specialized" in Agricultural Feedstocks and Chemicals (Indiana, Illinois, Iowa, and Tennessee);
- One of only seven states/territories that are "large and specialized" in Drugs and Pharmaceuticals (Indiana, California, New Jersey, North Carolina, Pennsylvania, Illinois, and Puerto Rico); and
- One of only four states that are "large and specialized" in Medical Devices and Equipment (Indiana, California, Minnesota, and Massachusetts).

Indiana thus enjoys a well-proven and differentiated position of strength in the life sciences, and benefits from a comparatively diverse life sciences profile. Only in the "Research, Testing and Medical Laboratories" sector is the state lagging, but even here the latest Battelle/BIO data show the state coming on strong with growth rates in the top quartile.

The agbiosciences actually have a presence across all the BIO/Battelle defined life science sectors. The presence in agricultural feedstocks and chemicals is obvious, but agbioscience is also a component of the other subsectors in "drugs and pharmaceuticals" (veterinary drugs, diagnostics and vaccines), "medical devices and equipment" (veterinary devices and equipment), the "research and testing" sector

[6] "Battelle/BIO State Biosciences Jobs, Investments and innovation 2014." Battelle Technology Partnership Practice, June 2014.
[7] Location Quotient = (State Employment in Sector in Year T / Total State Employment in Year T) / (National Employment in Sector in Year T / Total National Employment in Year T). A location quotient (LQ) of 1.0 equals parity with the expected level of employment given national averages. An LQ of 1.2 or higher is generally regarding as indicative of a "specialization" in an industry. A location quotient of <1.0 indicates that there is less presence of the sector in the economy than would be expected given national normative levels.

and “bioscience distribution”. The BIO definition (given BIO’s organizational focus) is quite focused on medical products and pure biotechnology—so while it provides an indication that Indiana is strong in agbioscience, it is not a sufficiently detailed analysis of this specific sector to be adequate for baseline and forward-planning purposes. For example, there are areas of R&D and production activity that Battelle considers to be agbioscience that are not incorporated under the BIO/Battelle definition—in areas such as agricultural production equipment, processing equipment, precision agriculture systems, etc.—that require a custom and broader definition of agbioscience to be deployed. Battelle thus employs a larger and customized definition of agbioscience within this study (see page 1).

What is clear is that there are considerable advantages to be gained in possessing diverse life science capabilities and assets. Strengths in basic and applied biological sciences and associated disciplines have application across a broad range of product and market opportunities. Capabilities in advanced genomics are, for example, broadly applicable to progressing innovation in agricultural, medical and industrial bio-based products. Indeed, as Figure 2 illustrates, there are substantial advantages to be gained for a state, such as Indiana, that has a significant footprint in multiple life science sectors because of the interrelationships between, and multidisciplinary nature of, bioscience markets.

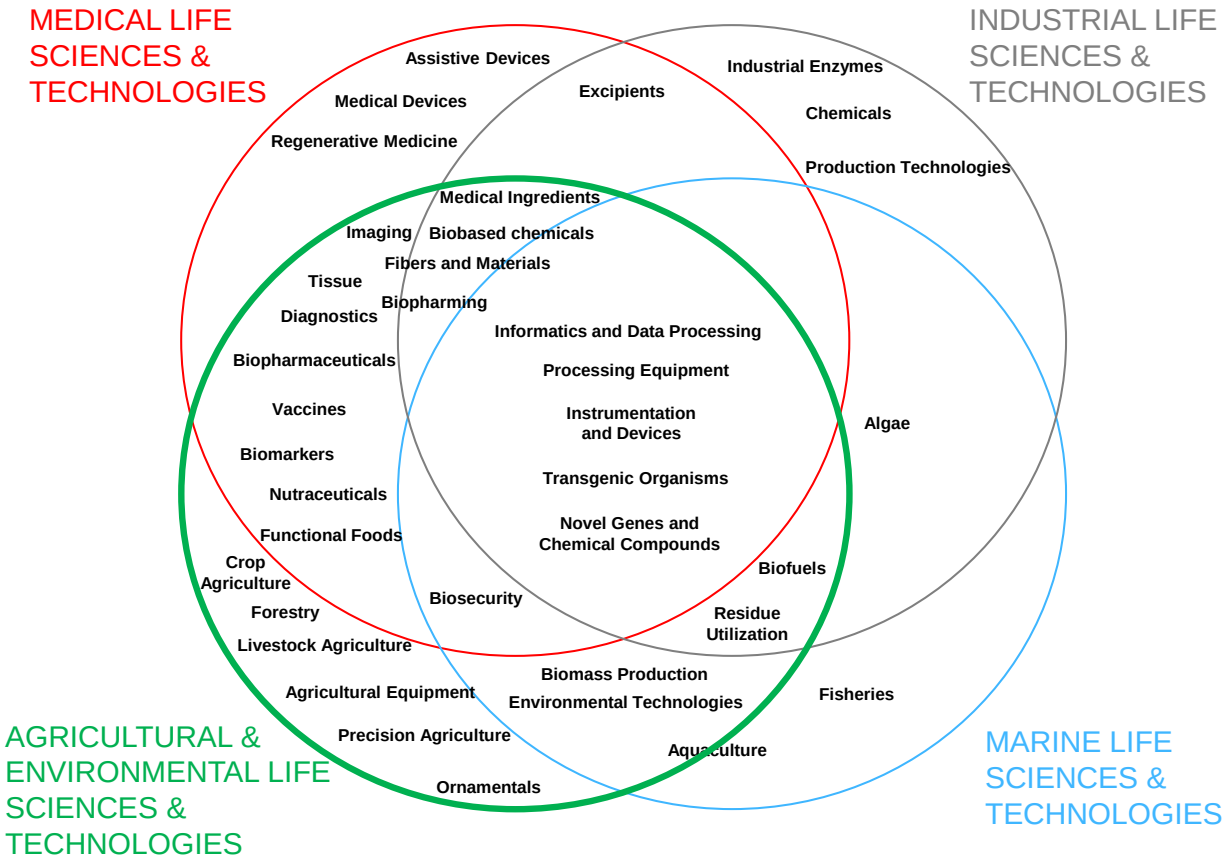


Figure 2. Life Science Domains and Interrelationships in the 21st Century Bioeconomy

Indiana's Position in Agbioscience Innovation—Purpose of the Study

Clearly "life sciences" embraces a very broad range of R&D and economic activity, ranging from basic biological discovery, through specialized sectors in biopharmaceuticals (both human and veterinary), medical devices, agricultural biotechnology, industrial biotechnology and other applications. The R&D and development ecosystems for these subsectors are, in turn, themselves specialized. Recognizing this, BioCrossroads and the Central Indiana Corporate Partnership (CICP) have determined a need for a specialized organizational focus on innovative agricultural sciences and associated engineering (agbiosciences) as a growth engine for the Indiana economy. A new initiative, termed the "Indiana Food and Agriculture Innovation Initiative" has been formed to support and guide further agbioscience-based innovation and economic development within Indiana.

In forming the Indiana Food and Agriculture Innovation Initiative ("IFAII" or the "Initiative"), Indiana's industry stakeholders have formally recognized the current and future promise of agbiosciences as an economic engine for Indiana. In particular, the Initiative is focusing on the development of the "**innovative**" agbiosciences subsector in the state—the component of the agriculture value-chain that is developing innovative new products either as:

- Inputs to primary agricultural production—for example advanced crop varieties and seeds, crop and livestock protection products, soil amendments, and precision agricultural equipment.
- Downstream value-added products that use the output of primary agricultural production as feedstock inputs for the creation of higher-value products for application to food, nutrition, health, materials, chemicals, polymers, textiles and other specialized industrial and consumer markets.

As a key starting point for the operations of IFAII, key stakeholders determined the need to commission an independent baseline study of the innovative agbioscience sector in Indiana. The envisioned study would:

- Define the innovative food and agriculture sector and profile the benefits to be expected from its ongoing advancement in the state as an innovation driver.
- Provide baseline quantitative data on the innovative food and agriculture sector, and associated subsectors, in Indiana currently—illustrating the importance of the sector to the state economy and its robust potential as a driver for economic growth.
- Provide illustrative short case studies or narrative vignettes of individual companies in Indiana that are major innovators in agbiosciences and on key areas of innovation and opportunity.
- Provide topline conclusions and recommendations for areas of initial focus for Indiana as suggested by the data and analysis.

Battelle's Technology Partnership Practice (Battelle TPP) was selected to conduct an in-depth baseline study of the innovative agbioscience sector in Indiana. Battelle TPP has direct experience in performing successful technology-based economic development strategic assignments in Indiana (including with BioCrossroads), a national and international reputation in advanced sector-specific analysis, and a broad track record in analysis and strategic planning focused on agbioscience.

Battelle TPP's analysis focuses very specifically on those innovative agbioscience economic activities that bracket (but do not include) primary agricultural production. Certainly the primary agricultural production industry is also home to innovation—innovations in agronomic practices (such as no-till farming, crop rotations, irrigation strategies, soil protection strategies) are developed by farmers and agricultural experiment stations for example—and help to enhance overall agricultural productivity and sustainability. Battelle and IFAII acknowledge the innovation and creativity of the primary production sector, but the Initiative (like BioCrossroads overall) is firmly focused on technology-based economic development and its ability to generate new employers and enhance business growth. As such, the focus of this project is on the sectors that develop and produce value-added technologies and products that either enhance agriculture itself, or which convert agricultural output into innovative value-added products.

As previously noted, the agbioscience sector is a connected value-chain of economic activity ranging from inputs to production through to specific value-added outputs (see Figure 1). However, the assessment for Indiana that follows is very much focused on defining and evaluating the "innovative" agbioscience sector—that is, the components of the agbioscience value-chain that are engaged in R&D and the production of specialized technologies and products for application in agriculture, or that use technology and innovation to produce value-added, further processed products from agricultural commodities.

Based upon discussions with the IFAII, Battelle performed two sets of analysis. In Chapter 2 the entire agbioscience and agriculture value-chain is quantified for Indiana (irrespective of the degree of innovation occurring in individual component areas of the value-chain), providing an overview of data for employment, number of business establishments, average wage levels and change in employment between 2003 and 2012. Also quantified in this analysis is the location quotient for each subsector, which measures the degree of Indiana's comparative specialization in each subsector. The analysis in Chapter 2 uses North American Industry Classification System (NAICS) codes as the basis for the analysis

In Chapter 3, Battelle analyzes through a variety of quantitative data analytic tools, the level of agbioscience research being undertaken within Indiana. In Chapter 4, Battelle then focuses on the areas of innovation that are driving Indiana's agbioscience industrial sector. This analysis goes beyond NAICS codes to examine individual companies and other institutions in Indiana engaged in innovative agbioscience activity. NAICS codes are "catch-all" broad categories with varying levels of innovation occurring across actors within each code. The goal of Battelle's analysis was to go deeper—looking at individual companies to determine their innovation activity and then placing those companies into innovation driver segments. Battelle examined a series of data resources in order to identify innovative companies and areas of agbioscience R&D occurring in the state, examining:

- Scientific and academic papers produced by Indiana-based researchers;
- Patents assigned to Indiana inventors and Indiana companies;
- SBIR and other early-stage innovative company financial awards; and
- Identification of individual companies in Indiana classified within agbioscience subsectors likely to comprise significant innovation activity.

Chapter 2. Indiana's Agbioscience Industry Profile

Introduction

The agbioscience sector is dynamic, transforming over time as technology and continuous innovation in the life and plant sciences advance research and commercial opportunities. Research breakthroughs and laboratory discoveries in plant and animal genetics, healthcare, ecology, and nutrition are significantly impacting and driving the evolution of the entire agbioscience industry.

The agbioscience sector reflects an overall trend in the U.S. economy, a shifting away from emphasis on traditional raw material and physical labor inputs toward intellectual capital, new technologies, and knowledge. Traditional agricultural entities find themselves in a new role, acting not only as a producer of food and related goods, but also as a leader in a broad array of applied bioscience areas. States with a traditional economic base in agriculture have the opportunity to embrace advances in technology and the biosciences to diversify and enhance the local economy.

Data and Methodology

The following economic analysis examines Indiana's agbioscience composition over the last decade. The report highlights key growth sectors and employment trends (both positive and negative) across a range of major agbioscience subsectors, as well as detailed component industries based on the North American Industrial Classification System (NAICS).

The NAICS is the official federal government system for classifying establishments and their activities into the appropriate sectors. The NAICS is based on the production processes of firms and categorizing them in groups with other establishments engaged in the same or similar activities. NAICS industries at the most detailed (six-digit) level were selected for this analysis and together make up the major sectors and subsectors. Using this system, industries at the six-digit level of detail were chosen. These detailed industries were aggregated up to the six major subsectors of the agbioscience industry. A full list of NAICS codes and the corresponding agbioscience subsector appears in Table A-1 of Appendix A.

The following economic analysis examines data and corresponding trends in Indiana and the entire United States in the agbioscience sector from 2003 to 2012. For the employment analysis, Battelle selected the BLS QCEW program data. The QCEW data (formerly known as the ES-202 program) are the most current, detailed state- and county-level industry establishment, employment, and wage figures available.[8] Battelle receives an "enhanced" version of these state and county data from a private vendor, the Minnesota IMPLAN Group, Inc.

The QCEW program, a cooperative program involving BLS and the State Employment Security Agencies, produces a comprehensive tabulation of employment and wage information for workers covered by state

[8] In general, QCEW monthly *employment* data represent the number of covered workers who worked during, or received pay for, the pay period that included the 12th day of the month. Virtually all workers are reported in the state in which their jobs are located. Covered private-industry employment includes most corporate officials, executives, supervisory personnel, professionals, clerical workers, wage earners, piece workers, and part-time workers. It excludes proprietors, the unincorporated self-employed, unpaid family members, and certain farm and domestic workers. An *establishment* is an economic unit such as a farm, mine, factory, or store that produces goods or provides services. It is typically at a single physical location and engaged in one, or predominantly one, type of economic activity for which a single industrial classification may be applied. *Total wages*: Covered employers in most states report total compensation paid during the calendar quarter, regardless of when the services were performed. A few state laws, however, specify that wages be reported for or be based on the period during which services are performed, rather than for the period during which compensation is paid. Under most state laws or regulations, wages include bonuses, stock options, severance pay, the cash value of meals and lodging, tips and other gratuities, and—in some states—employer contributions to certain deferred compensation plans such as 401(k) plans.

unemployment insurance (UI) laws and federal workers covered by the Unemployment Compensation for Federal Employees (UCFE) program.[9]

It is important to note the exclusion of many workers on small farms from the QCEW data. The program data are collected from UI records and do not cover self-employed farmers and some wage and salary farm workers. It is obvious that a critical component of any Indiana-specific economic analysis is the role of the small farm and its activities. Recognizing this limitation in the data, one must look to other data sources to account for this farm-related activity.

Economic data on family farms are available from other sources, including farm and farm-related employment estimates from the USDA's Economic Research Service (ERS) and the U.S. Department of Commerce's Bureau of Economic Analysis (BEA). The USDA's National Agricultural Statistics Service (NASS) also publishes useful information on the number and size of farms, as well as crop, livestock, and other agricultural production metrics. Data from these sources are used to supplement the BLS data for the economic analysis. Employment estimates from BLS may differ significantly from other sources due to differences in concepts, definitions, and estimation methodologies.

BEA estimates of the number of self-employed farm proprietors are used extensively in this report. County, state, and national estimates are available through 2012. Though they are derived from a data source separate from the BLS data, farm proprietors are included in charts and tables in this report, and aggregated with totals for the incorporated agricultural production subsector in order to paint a fuller picture of the entire agricultural production industry in Indiana.

Size and Performance of Indiana's Agbioscience Industry

The total agbioscience industry in Indiana employed 133,765 personnel across the full value-chain in 2012 (Table 2). Not including Primary Production (farming), the remaining segments of the agbioscience industry employed 68,849 (51.5 percent of total value-chain employment).

Table 2. Indiana Agbioscience Employment, Establishments, Wages and Specialization[10]

Agbioscience Segment	2012 Metrics				Recent Employment Performance				
	Estabs.	Employ.	Avg. Wage	Special-ization	Change Through Recession, 2003-2009	Change Post Recession, 2009-2012	Total Change, 2003-2012	U.S. Post Recession Change	U.S. Total Period Change
Ag & Biological Research, Testing, and Services	759	7,826	$36,025	0.80	12.8%	5.3%	18.8%	4.1%	22.6%
Agricultural & Biomass Processing	139	4,904	$54,194	**1.51**	4.8%	6.5%	11.7%	0.3%	-15.7%
Food, Nutrition, & Health	602	36,009	$39,558	0.99	7.5%	3.3%	11.0%	1.2%	-2.4%
Inputs to Production	798	13,341	$65,780	**2.64**	4.3%	4.8%	9.3%	-29.9%	-32.9%
Primary Production	60,256	64,916	$32,330*	0.97	-1.6%	0.1%	-1.5%	0.6%	-1.7%
Wholesaling, Distribution, and Storage Operations	384	6,768	$43,495	1.00	7.8%	4.4%	12.5%	3.5%	9.4%
Total Agbioscience Industry	62,938	133,765	$43,430*	1.04	2.7%	2.1%	4.9%	-0.5%	-2.1%

Source: Battelle analysis of Bureau of Labor Statistics, QCEW data from IMPLAN, farm proprietor employment data from the Bureau of Economic Analysis, and farm proprietor establishment data from USDA NASS.
* Average wage estimate for corporate workers only.

[9] Major exclusions from UI coverage, and thus from the QCEW data, include self-employed workers (both farmers and non-agriculture), some wage and salary agricultural workers, unpaid family workers, railroad workers, and some state and local government workers.
[10] Totals may not sum due to rounding.

Outside of farms (Primary Production), there are 2,682 business establishments in the value-chain in Indiana, with the largest number (798 establishments) in the provision of Inputs to Production (e.g., farm-based inputs such as seeds, agricultural chemicals, livestock nutrition products and animal health products), and a similar number (759 establishments) in Agricultural & Biological Research, Testing and Services. In terms of employment, the largest subsector, outside of farming, is in Food, Nutrition, and Health, with 36,009 employees, followed by Inputs to Production with 13,341 employees.

Two of the agbioscience subsectors stand out as specializations for Indiana (as defined by location quotient or LQ). Inputs to Production has an LQ of 2.64, indicating that there is a 1.64 times higher level of employment in this sector in Indiana than would be expected given national averages. The other specialized sector is Agricultural and Biomass Processing with an LQ of 1.51. The other subsectors are at or close to national normative levels of employment concentration, except for the Agricultural & Biological Research, Testing and Services sector, which is comparatively less specialized, only having an LQ of 0.80 (or 80 percent of the level of employment expected given national normative levels).

Inputs to Production is clearly a highly important agbiosciences subsector for Indiana. Highly concentrated and employing more than 13,000 workers, this subsector also provides high comparative levels of wages, with an average wage of $65,780—significantly higher than the average wage level in Indiana (which in 2012 stood at $41,356). The other specialized sector of Agricultural and Biomass Processing also demonstrates high wage levels, with an average wage of $54,194.

An important finding is that ***in all cases (other than Primary Production) Indiana has seen employment grow between 2003–2012.*** Post-recession (2009–2012) the agbioscience subsectors (again other than farming) have ranged in employment growth from 3.3 percent to 6.5 percent. Also, ***each of these subsectors has grown at a rate faster than the U.S. average in the post-recession time period.***

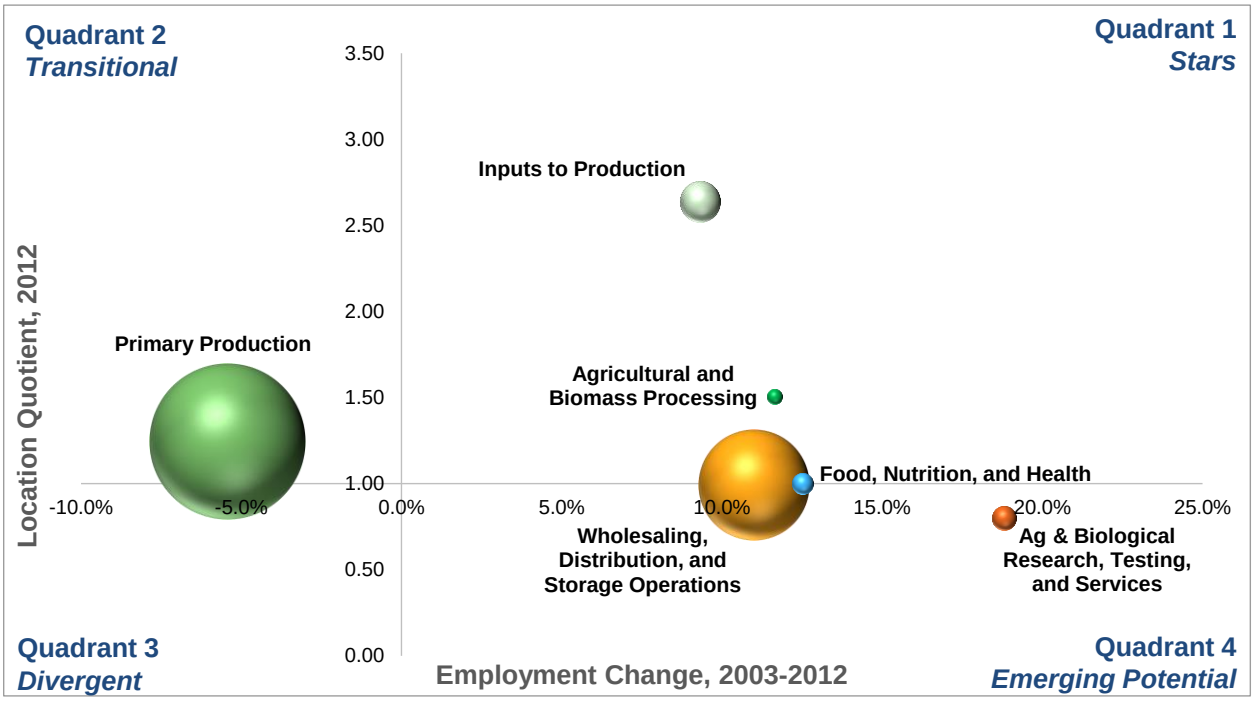
Table 3 breaks the agbioscience segments into further detail, showing data for the individual sub-segments incorporated under each segment.

Table 3. Indiana Agbioscience Industry Detail

Agbioscience Segment	2012 Metrics				Recent Employment Performance		
	Estabs.	Employ.	Avg. Wage	Special-ization	Change Through Recession, 2003-2009	Change Post Recession, 2009-2012	Total Change, 2003-2012
Ag & Biological Research, Testing & Services	759	7,826	$36,025	0.80	12.8%	5.3%	18.8%
Biological and Agricultural R&D	84	977	$81,658	0.35	2.8%	21.5%	24.9%
Testing Laboratories	35	168	$54,072	0.74	12.4%	11.0%	24.7%
Veterinary Services	641	6,681	$28,897	0.99	14.2%	3.2%	17.8%
Agricultural & Biomass Processing	139	4,904	$54,194	1.51	4.8%	6.5%	11.7%
Agricultural Processing	26	2,839	$64,339	2.26	7.2%	-2.0%	5.1%
Biomass Processing	113	2,065	$40,250	1.03	1.1%	20.9%	22.2%
Food, Nutrition & Health	602	36,009	$39,558	0.99	7.5%	3.3%	11.0%
Beverage Manufacturing	93	3,913	$40,467	1.01	17.9%	3.7%	22.2%
Botanicals, Diagnostics, and Biological Products	15	394	$49,305	0.28	45.5%	-6.0%	36.8%
Food Processing & Manufacturing	494	31,702	$39,324	1.02	6.0%	3.3%	9.5%
Inputs to Production	798	13,341	$65,780	2.64	4.3%	4.8%	9.3%
Ag Machinery & Equipment	338	5,821	$51,237	1.37	-1.4%	6.5%	4.9%
Agricultural Chemicals	21	2,284	$102,699	2.86	-16.0%	8.4%	-8.9%
Agricultural Inputs Wholesaling	437	4,481	$53,781	1.87	23.1%	0.0%	23.0%
Veterinary Products	2	755	$137,446	45.68	32.1%	12.5%	48.6%
Primary Production	60,256	64,916	$32,330*	0.54	-1.6%	0.1%	-1.5%
Agricultural & Biomass Production (Corporate)	1,048	7,436	$32,817	0.37	-5.8%	11.9%	5.4%
Livestock Production (Corporate)	508	6,436	$31,766	1.12	18.9%	11.2%	32.2%
Farm Proprietors	58,700	51,044	N/A	1.24	-2.9%	-2.6%	-5.4%
Wholesaling, Distribution & Storage Operations	384	6,768	$43,495	1.00	7.8%	4.4%	12.5%
Agricultural Commodity Wholesaling	204	2,434	$41,721	1.52	-1.5%	-9.8%	-11.1%
Food Product Wholesaling	139	2,306	$45,181	0.60	12.5%	12.5%	26.6%
Warehousing and Storage	41	2,028	$43,707	1.53	19.4%	16.8%	39.5%
Total - Agbioscience Industry	62,938	133,765	$43,430	1.04	2.7%	2.1%	4.9%
Total Private Sector (***Not Including Farm Proprietors)***	153,450	2,418,241	$41,356	1.00	-5.4%	5.3%	-0.4%

The more detailed breakout in Table 3 shows that the Agricultural & Biological Research, Testing and Services segment is actually quite small in terms of employment within focused agbioscience R&D enterprises (977 jobs in the Biological and Agricultural R&D sub-segment, distributed across 84 establishments). The majority of the jobs in Agricultural & Biological Research, Testing and Services (6,681 or 85 percent of the segment total) are in the Veterinary Services sub-segment, and Battelle would expect that this sub-segment only has limited engagement in innovation activity.

Further insight into the comparative performance of Indiana's agbioscience subsectors can be derived from the graphs shown in Figures 3 and 4.

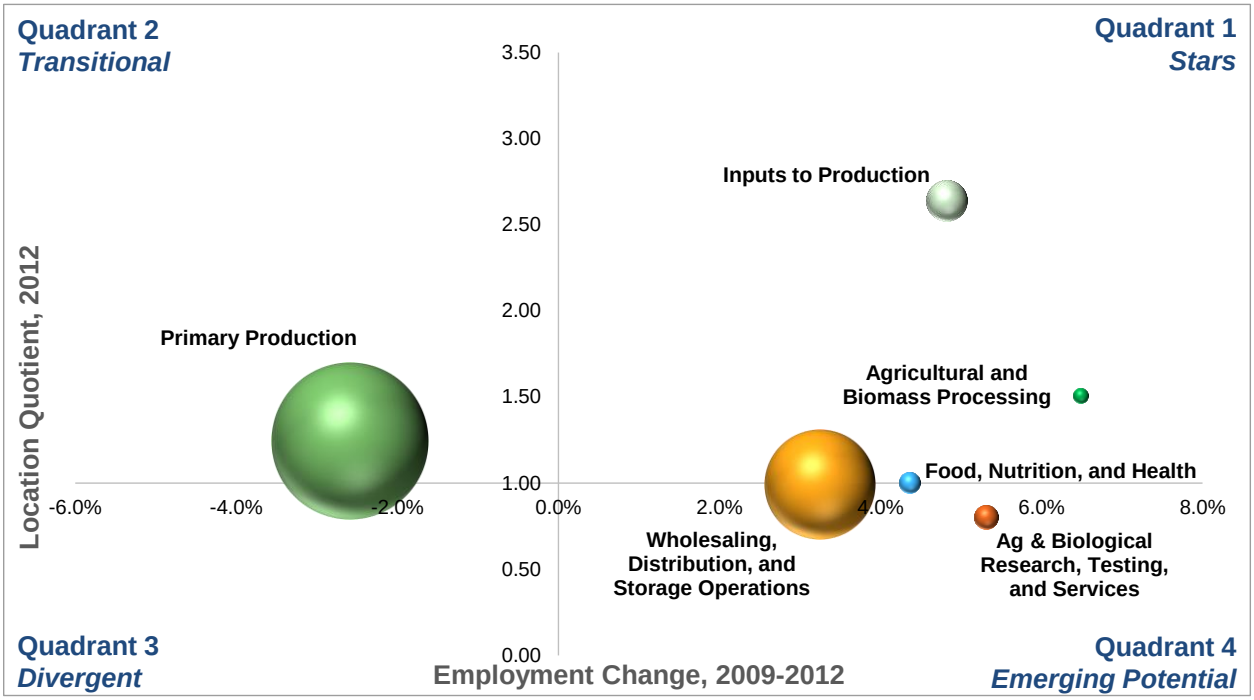


Source: Battelle analysis of Bureau of Labor Statistics, QCEW data from IMPLAN, farm proprietor employment data from the Bureau of Economic Analysis, and farm proprietor establishment data from USDA NASS.

Figure 3. Comparative Agbioscience Segment Performance: 2003–2012

In Figure 3, the size of each bubble is proportionate to the level of employment in each respective agbioscience segment. The vertical (y) axis measures the location quotient, while the horizontal (x) axis measures employment change. As such, the bubble chart divides into four quadrants. Quadrant 1 comprises "star" segments—those agbioscience segments that have both comparative specialization for Indiana (having an LQ greater than 1.0) and that have experienced positive employment growth between 2003-2012. Quadrant 4 comprises potentially up-and-coming segments—those agbioscience segments that are not yet at a specialized LQ, but are demonstrating positive growth. The only Indiana agbioscience subsector that is not in either Quadrant 1 or 4 is primary production (farming), which has experienced declining employment levels. It should be noted, however, that primary production has tended to see declining employment levels steadily in the United States for decades, primarily as a result of substantial increases in on-farm productivity as a result of innovations in agronomy and technological advancements in inputs to production.

Figure 4 presents the similar data, but with employment growth focused on the post-recession time period of 2009–2012. It presents a similar overall picture to the full 2003–2012 time period, but the growth rates for each subsector are comparatively lower (albeit still positive, except for Primary Production).



Source: Battelle analysis of Bureau of Labor Statistics, QCEW data from IMPLAN, farm proprietor employment data from the Bureau of Economic Analysis, and farm proprietor establishment data from USDA NASS.

Figure 4. Comparative Agbioscience Segment Performance Post-Recession: 2009–2012

Finally, the continued growth in Indiana of the agbioscience industry is evidenced by the number of company expansions/attractions. As Table 4 indicates, Indiana has continued to experience significant growth in investments in both new and expanded facilities across most of the agbiosciences sectors since the recession. From 2009–2013, 60 investment commitments were made in agbiosciences totaling nearly $1.4 billion.

Table 4. Agbioscience Investment Commitments for New and/or Expanded Facilities, 2009–2013

Agbioscience Segment	# of Deals	Level of Investment
Agricultural & Biomass Processing	1	$5,367,000
Food, Nutrition & Health	39	$743,910,619
Inputs to Production	11	$442,255,354
Primary Production	4	$51,740,000
Wholesaling, Distribution & Storage Ops	5	$124,881,559
Total	**60**	**$1,368,154,532**

Source: Indiana Economic Development Corporation.

Primary Agriculture Production in Indiana

The previous section described the employment and segment basis for the Indiana agbioscience "industry". Yet, it is the "size", "value", and "what is produced" in terms of primary agricultural production that underlies the strength of the overall industry and guides and shapes the state's innovations in the agbiosciences.

Indiana contains 19.4 million acres of farm and forest land, constituting 83 percent of the state's total land area. Within this land area approximately 60,000 farms account for 14.7 million acres at an average farm size of 245 acres. The total value of the state's agricultural products sold in 2012 was $11.2 billion, ranking 10th among the states. While impressive in its own right, considering Indiana ranks 18th in terms of farm land area further indicates the productive nature of the Indiana's agriculture production. Of the total $11.2 billion in agricultural sales $4.7 billion, or 42 percent is exported, which places Indiana 8th in state agricultural export rankings.

Of this $11.2 billion in production value of sales, five commodities account for the vast majority:

- Corn – $4 billion
- Soybeans – $2.9 billion
- Hogs and pigs – $1.2 billion
- Poultry and eggs – $1.1 billion
- Dairy – $660 million

Together these five commodities account for nearly $9.9 billion of Indiana's agricultural products sold and 88 percent of the total.

Though commodity prices vary from year to year, Indiana's farmers have maintained a solid growth in net cash income over the last few years, reaching $4.8 billion in 2012. This level represents a solid 11 percent increase over the 2011 figure of $4.3 billion for the state's farmers and a very strong 39 percent increase over the 2010 figure of $3.1 billion in 2010.

Summary

The agbioscience industry accounts for nearly 134,000 jobs in the state and has been outpacing overall private sector job growth since 2003. Though the range of employment, types of jobs, and wages vary between the different segments and sub-segments, wages in the industry are on par with or substantially exceed overall private sector wages. Four segments have positive growth rates and relative concentrations above the national average—Inputs to Production; Agricultural and Biomass Processing; Food, Nutrition, and Health; and Wholesale, Distribution, and Storage Operations. While Primary Production may be on a decline in terms of job growth for the state, it continues to be a major economic driver for Indiana accounting for more than $11 billion in sales in 2012.

Chapter 3. Indiana's Agbioscience Research Enterprise

Academic Agbioscience R&D in Indiana

In academic agbioscience research, Purdue University dominates Indiana's public research enterprise. As Indiana's 1862 Morrill Land Grant Act University, Purdue has a continuous history of engagement in agricultural and associated research, and today accounts for 99 percent of university-based agbioscience research performed in Indiana.

Between 2003 and 2011, NSF higher education R&D expenditure data (Figure 5) show that Indiana benefited from a positive growth trend in academic agbioscience research, growing from $88.4 million in 2003 to a high of $119.4 million in 2011.[11] 2012 data show a moderate decline in academic research to $118 million, although such a small change may well reflect just a single program grant coming to an end at Purdue. Overall, between 2003 and 2012, Indiana has experienced 34 percent growth in its agbioscience academic research expenditures.

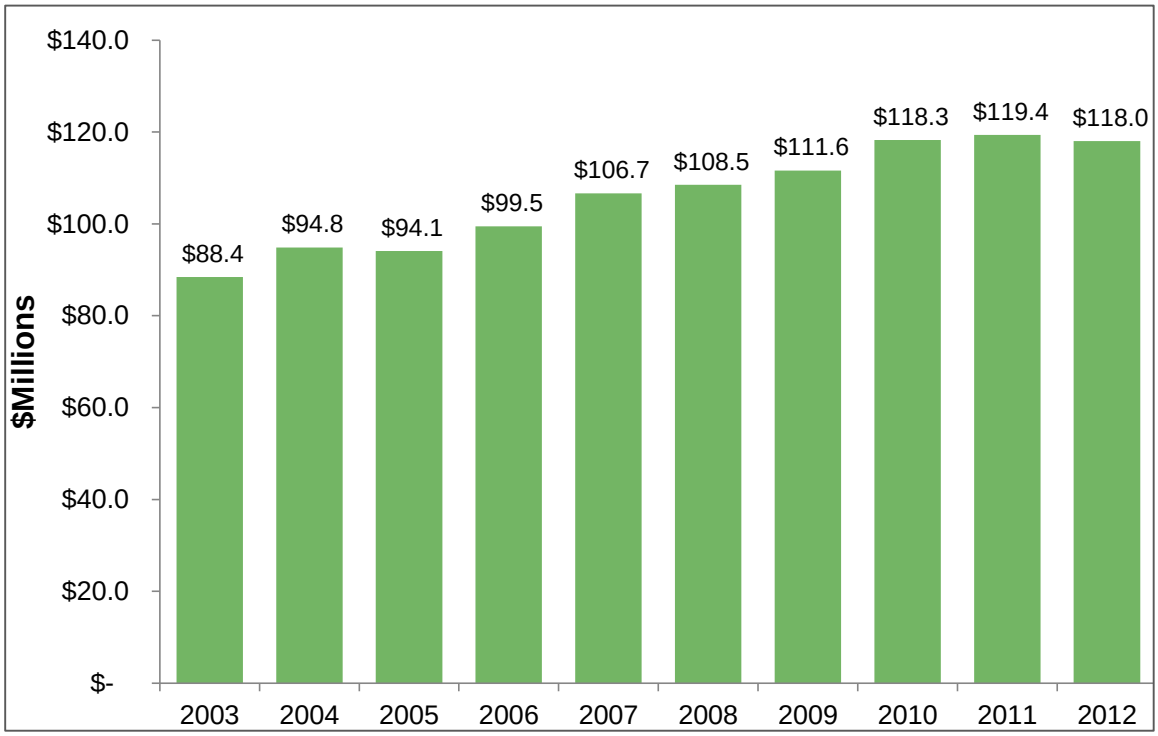


Figure 5. Annual Academic Agbioscience Research Expenditures in Indiana 2003–2012

Academic research output is typically measured in terms of publications. Battelle reviewed publications data for Indiana academic institutions across three broad research field categories:

- Core agbioscience disciplines;
- Life science disciplines whose research activity can hold significant implications for agbioscience applications; and

[11] National Science Foundation, Higher Education Research and Development expenditure survey data (and predecessor Academic R&D expenditure survey), 2003-2011. Includes data reported by institutions by R&D field.

- Disciplines more peripherally related to agbioscience content.

Table 5 shows publications data for 2009 through June 2014, indicating that across all three macro categories over 15,000 publications were produced by Indiana institutions.

Table 5. Indiana Publications in Agbiosciences and Ancillary Disciplines (2009 to June 2014)[12]

	Discipline	Publications	Share of All State Pubs	Concentration
Principal Agriculture and Agbioscience Fields	PLANT SCIENCES	782	3.60%	1.26
	ANIMAL SCIENCES	677	1.43%	1.15
	VETERINARY MEDICINE ANIMAL HEALTH	428	0.90%	1.25
	AGRICULTURE AGRONOMY	366	0.77%	1.22
	FOOD SCIENCE NUTRITION	353	0.74%	0.92
	ANIMAL PLANT SCIENCE[13]	341	0.72%	1.68
	ENTOMOLOGY PEST CONTROL	281	0.59%	1.08
	AGRICULTURAL CHEMISTRY	143	0.30%	1.10
Related Basic Research Fields	ENVIRONMENT ECOLOGY	1,477	3.12%	0.90
	BIOCHEMISTRY BIOPHYSICS	1,090	2.30%	0.84
	MOLECULAR BIOLOGY GENETICS	652	1.38%	0.96
	MICROBIOLOGY	588	1.25%	0.64
	BIOLOGY	484	1.02%	0.93
	CELL DEVELOPMENTAL BIOLOGY	409	0.86%	0.60
	IMMUNOLOGY	369	0.78%	0.50
	AQUATIC SCIENCES	243	0.51%	0.48
	BIOTECHNOLOGY APPLIED MICROBIOLOGY	157	0.34%	0.84
Ancillary and Related Application Fields	CHEMISTRY ANALYSIS	1,466	3.09%	1.23
	EARTH SCIENCES	1,237	2.61%	0.75
	MULTIDISCIPLINARY	1,184	2.50%	0.86
	CHEMISTRY	947	1.99%	1.11
	ORGANIC CHEMISTRY POLYMER SCIENCE	606	1.28%	1.02
	ENVIRONMENTAL ENGINEERING ENERGY	439	0.92%	0.87
	CHEMICAL ENGINEERING	360	0.76%	1.18
	EXPERIMENTAL BIOLOGY	298	0.63%	0.99
	CLINICAL IMMUNOLOGY INFECTIOUS DISEASE	259	0.56%	0.55

In the first category of Principal Agriculture and Agbioscience Fields, Indiana generated 3,371 publications with the top fields being Plant Sciences (782) and Animal Sciences (677). It should be noted

[12] Source: Thomson Reuters Current Contents Connect (Web of Science) Database (7/1/2014).
[13] "Animal Plant Science" Category Description: Animal & Plant Sciences covers resources in animal science, which focus on laboratory animal science and zoology; the plant science resources cover cellular and molecular biology or physiology of plant cells and plant systems. Topics include molecular biology, molecular genetics, plant-microbe interactions, physiology and cell biology, and biochemistry. A limited number of botany and general plant biology resources are also included. Resources on veterinary medicine and veterinary science, husbandry, and general zoology are excluded.

that publications in academic journals are not the exclusive domain of academic scientists. Indeed, companies in Indiana, especially Dow AgroSciences, demonstrate significant publishing activity.

The "concentration" value shown in Table 5 provides a measure of whether the volume of publishing in the discipline is higher or lower in Indiana than would be expected given national normative levels of publishing in that discipline. A concentration value of 1.0 means that the level of publishing is the same in Indiana as would be expected given national normative levels. A number below 1.0 indicates publishing activity at a lower level than expected, while a number above 1.0 indicates a larger than anticipated share of publishing activity in that discipline. A value of 1.2 or higher likely indicates a comparative specialization in that discipline in Indiana (with activity =>20 percent higher than national normative levels). It is evident from this analysis that in the "principal agriculture and agbioscience fields" category, Indiana demonstrates a relative specialization in several disciplines, including:

- Plant Sciences, 782 publications (1.26 concentration)
- Veterinary Medicine and Animal Health, 428 publications (1.25 concentration)
- Agriculture and Agronomy, 366 publications (1.22 concentration)
- Animal and Plant Science, 341 publications (1.68 concentration)

In addition, the concentration figure is above 1.0 for Animal Sciences (1.15), Agricultural Chemistry (1.1), and Entomology and Pest Control (1.08). Only in Food Science and Nutrition is the Indiana publications concentration figure lower than 1.0 (at 0.92).

In the related Basic Research Fields disciplines of life sciences, Indiana has below average concentration in all of the listed disciplines. In the more peripherally related Ancillary and Related Application Fields category, it is evident that the chemistry-related disciplines are a clear publishing strength area for Indiana (comprising Chemistry, Chemistry Analysis and Chemical Engineering).

OmniViz™ Analysis of Indiana Agbioscience Publications

Battelle frequently employs the OmniViz™ pattern recognition and clustering software system to provide detailed quantitative analysis regarding research strength areas. OmniViz™, originally developed by Battelle, uses pattern recognition algorithms to cluster research fields into grouped strength areas. This analysis is particularly valuable because it allows free association of words and phrases, rather than forcing clustering on preselected key words—thus, there is no *a priori* bias to the clusters identified.

Battelle performed the Indiana agbioscience analysis on research publication abstract data, covering the time period of 2009 through June 2014. A total of 3,169 agbioscience papers/publications were incorporated in the analysis. The performance of the clustering analysis involves the following steps:

- **Step 1—Content Development**: Developing a data set with sufficient descriptive content (publication abstracts).
- **Step 2—Pattern Recognition**: The analysis generates clusters where grant activities have apparent relationships and produces a series of words to describe and link these cluster areas.
- **Step 3—Interpretation and Grouping by Battelle**: The identification of key themes and groupings that result from OmniViz™ require analytical expertise to interpret and explain the types of technologies and specific activities that are represented in the cluster items.

OmniViz™ output is provided in both graphical and spreadsheet table formats. This allows for visualization of key cluster areas and deeper investigation of the actual grants or patent information contained within each apparent cluster.

Figure 6 illustrates part of the basic spreadsheet output and interpretation of resulting metaclusters and major themes. The OmniViz™ analysis identified 38 distinct clusters of agbioscience research publishing activity by Indiana-based authors (primarily, but not exclusively, Purdue University researchers). These

clusters range in size from a high of 352 papers in “water and soil” to the smallest cluster with just six records “wood materials engineering”.

Cluster ID (0-37)	Number of Records	Major Theme	MetaCluster Name	% of Records with Bold Term	Key Terms	Color key is after the cluster data. **Bold** term is single largest term within the Major/Minor Topics.												
29	235	Animal Science	Animal scence: sexual behavior	83%	social	mate	sex	**behavior**	evolution	food								
0	102	Animal Science	Predator/prey zoology	69%	predator	distance	prey	lizard	predation	flight	escape	initiation	speed	forage	**behavior**	sceloporu	virgatus	skink
33	49	Animal Science	Animal science: dairy lactation	82%	**milk**	**dairy**	bovine	farm	cattle	holstein	lactation	herd	lactate	calve	production			
9	40	Animal Science	Poultry/egg: livestock housing	83%	**egg**	poultry	hen	cage	chicken	stress	trait	leghorn	strength	welfare	behavior	lay		
6	6	Biomaterials	Wood materials engineering	100%	**wood**	joint	fiber	shape	round	construct	tenon	mortise						
14	352	Eco Resources	Water and soil	45%	**water**	soil												
17	172	Eco Resources	Oak trees	61%	**tree**	forest	seedling	leaf	root	oak	quercus	planted	water	red	growth	species	plant	
16	162	Eco Resources	Ecology: forest ecology	88%	**forest**	habitat	landscape	ecosystem	tree	ecology	spatial	species						
20	29	Eco Resources	Ecological impacts of land use	86%	**land use**	land	forest	landscape	climate cl	climate	ecosyster	crop	global	spatial	conversio	urban	watershe	river
27	24	Eco Resources	Ecology: conservation biology	67%	**diversity**	climate cl	habitat	climate	evolution	haplotype	conserva	biodiversi	adaptation	threaten	manage	endanger	species	
19	47	Economics	Agricultural economics	85%	market	price	nutrition	**food**	agriculture									
31	22	Economics	Agricultural economics	77%	**farm**	farmer	market	price	labor	agricultur	economic	production						
35	54	Entomology	Entomology: beetles	65%	**insect**	larva	pest	larval	beetle	insecticid	coleopter	physiolog	life	entomolo	species			
30	28	Food Safety	Food safety: pathogen detection	75%	**pathogen**	detection	defense	infection	food	salicylic a	arabidops	fungal	transcript	tested	polymera	cinerea	assay	sensitive
3	8	Food Safety	Food safety: tomato treatment	100%	**tomato**	fruit	pathogen	gas	food	inactivatic	dioxide	fresh	treatment	technolog	condition			
1	55	Genomics	Evolutionary genomics	78%	genome	deoxyribo	chromos	genus	**evolution**	genomics	phylogen	divergenc	comparat	sequence	gene	species		
2	22	Genomics	Phylogenetics	100%	**genus**	taxonomy	phylogen	systematic	phylogen	taxon	morpholo	evolution	clade	species				
32	280	Livestock Nutrition	Animal science: poultry nutrition	68%	broiler	energy	poultry	chicken	**feed**	protein	food	diet						
15	146	Livestock Nutrition	Animal science: porcine meat and feed	86%	**porcine**	meat	carcass	muscle	pen	feed	protein	animal	treatment	growth				
34	96	Livestock Nutrition	Distillers grains as livestock feed	76%	**grain**	dry	corn	soluble	distillers	feed	ddgs	protein	food					
10	66	Livestock Nutrition	Cattle nutrition	61%	**bovine**	dairy	cattle	serum	milk	beef	plasma	liver	veterinary	protein	holstein	feed	calf	food
37	202	Plant Science	Plant science: starch crops	88%	**corn**	starch	crop	hybrid	rice	food	plant							
4	187	Plant Science	Plant science; biosynthesis/physiology	73%	enzyme	biosynthe	**protein**	arabidopsis	encode	gene expr	physiolog	plant	gene	cell				
5	80	Plant Science	Plant science: salt/stress tolerance	89%	**stress**	tolerance	salt	leaf	water	sodium	drought	arabidops	protein	accumula	abiosis	encode	physiolog	gene expr
28	64	Plant Science	Crop science: glyphosate resistance	94%	**weed**	herbicide	glyphosat	crop	soybean	corn	seed	tolerance	soil	grower	canadens	evolution	biotype	resistant
36	54	Plant Science	Plant science: life cycle/growth	93%	**root**	phosphat	leaf	arabidopsis	protein	accumula	physiolog	auxin	starvation	phenotyp	homeosta	plant	growth	gene
24	52	Plant Science	Crop science: entomology (flies)	94%	**fly**	diptera	insect	wheat	pest	fruit	larva	attack	tephritida	hessian	entomolo	mayetiola	destructo	cecidomy
26	50	Plant Science	Crop science: soybean agronomy	88%	**crop**	soybean	corn	sustainability	weed	food	grow	agricultur	production					
8	42	Plant Science	Crop science: soy and corn	100%	**soybean**	seed	genome	cultivar	crop	corn	glycine	protein	evolution	stage	plant			
22	40	Plant Science	Crop science: wheat	88%	**wheat**	cultivar	winter	head	leaf	grain	marker	virus	triticum	aestivum	rust	fusarium	blight	barley
11	25	Plant Science	Plant science: growth and development	100%	**fruit**	tomato	leaf	water	flower	cultivar	apple	solanum	stage	arabidops	plant			
12	21	Plant Science	Plant science: flowering	100%	**flower**	stem	floral	arabidopsis	grow	suppress	ribonuclei	inflorescc	developm	plant	show	time	gene	
21	15	Plant Science	Crop Science	100%	**cultivar**	crop	genotype	stem	grow	red	greenhou	plant	experime	compare	quality			
7	146	Veterinary Medicine	Canine veterinary medicine	100%	**canine**	veterinary	animal											
23	97	Veterinary Medicine	Veterinary infectious diseases	90%	**infection**	infect	prevalenc	virus	pathogen	veterinary	polymera	disease						
18	41	Veterinary Medicine	Feline veterinary medicine	90%	**feline**	canine	infection	lesion	veterinary	protein	diagnostic	animal	disease	diagnosis				
13	33	Veterinary Medicine	Equine veterinary medicine	100%	**equine**	veterinary	examinati	complicatior	animal									
25	25	Veterinary Medicine	Feline veterinary medicine	100%	**feline**	canine	veterinary	healthy	diagnose	internal m	examinati	abnormal	animal	disease				
	3169																	

Color Key	
Major Topics	-- Significant and driving impact on cluster formation. Provide all terms in 20% or more of cluster's records.
Minor Topics	-- Ancillary impact on cluster formation. Provide all terms in 20% or more of cluster's records.
Other Terms	-- No impact on cluster formation. Provide context on the records within the cluster. Provide key/unique terms in 40% or more of cluster's records

Figure 6. OmniViz™ Thematic Clustering of Indiana Agbioscience Publications 2009–2014 (June)

Table 6 simplifies the spreadsheet data to provide just a listing of the metaclusters, major themes, and associated publication counts. The data are again sorted from largest to smallest cluster in terms of publication volumes.

Table 6. OmniViz™ Themes and MetaClusters (Sorted by Number of Publications) – 2009 to June 2014

Publications	Major Theme	MetaCluster Name
352	Eco Resources	Water and soil
280	Livestock Nutrition	Animal science: poultry nutrition
235	Animal Science	Animal science: sexual behavior
202	Plant Science	Plant science; starch crops
187	Plant Science	Plant science; biosynthesis/physiology
172	Eco Resources	Oak trees
162	Eco Resources	Ecology: forest ecology
146	Livestock Nutrition	Animal science: porcine meat and feed
146	Veterinary Medicine	Canine veterinary medicine
102	Animal Science	Predator/prey zoology
97	Veterinary Medicine	Veterinary infectious diseases
96	Livestock Nutrition	Distillers grains as livestock feed
80	Plant Science	Plant science: salt/stress tolerance
66	Livestock Nutrition	Cattle nutrition
64	Plant Science	Crop science: glyphosate resistance
55	Genomics	Evolutionary genomics
54	Entomology	Entomology: beetles
54	Plant Science	Plant science: life cycle/growth
52	Plant Science	Crop science: entomology (flies)
50	Plant Science	Crop science: soybean agronomy
49	Animal Science	Animal science: dairy lactation
47	Economics	Agricultural economics
42	Plant Science	Crop science: soy and corn
41	Veterinary Medicine	Feline veterinary medicine
40	Animal Science	Poultry/egg: livestock housing
40	Plant Science	Crop science: wheat
33	Veterinary Medicine	Equine veterinary medicine
29	Eco Resources	Ecological impacts of land use
28	Food Safety	Food safety: pathogen detection
25	Plant Science	Plant science: growth and development
25	Veterinary Medicine	Feline veterinary medicine
24	Eco Resources	Ecology: conservation biology
22	Economics	Agricultural economics
22	Genomics	Phylogenetics
21	Plant Science	Plant science: flowering
15	Plant Science	Crop science
8	Food Safety	Food safety: tomato treatment
6	Biomaterials	Wood materials engineering

Table 7 aggregates the publication records across Battelle's definition of the major themes.

Table 7. Indiana Publications in Agbiosciences and Ancillary Disciplines (2009–June 2014)[14]

Major Theme	Number of Publications
Plant Science	832
Eco Resources	739
Livestock Nutrition	588
Animal Science	426
Veterinary Medicine	342
Genomics	77
Economics	69
Entomology	54
Food Safety	36
Biomaterials	6

Another perspective on the data is provided by referencing the data visualization graphic produced by OmniViz™ software together with Battelle's analysis of each cluster and apparent thematic groupings of clusters. This analysis is shown in Figure 7.

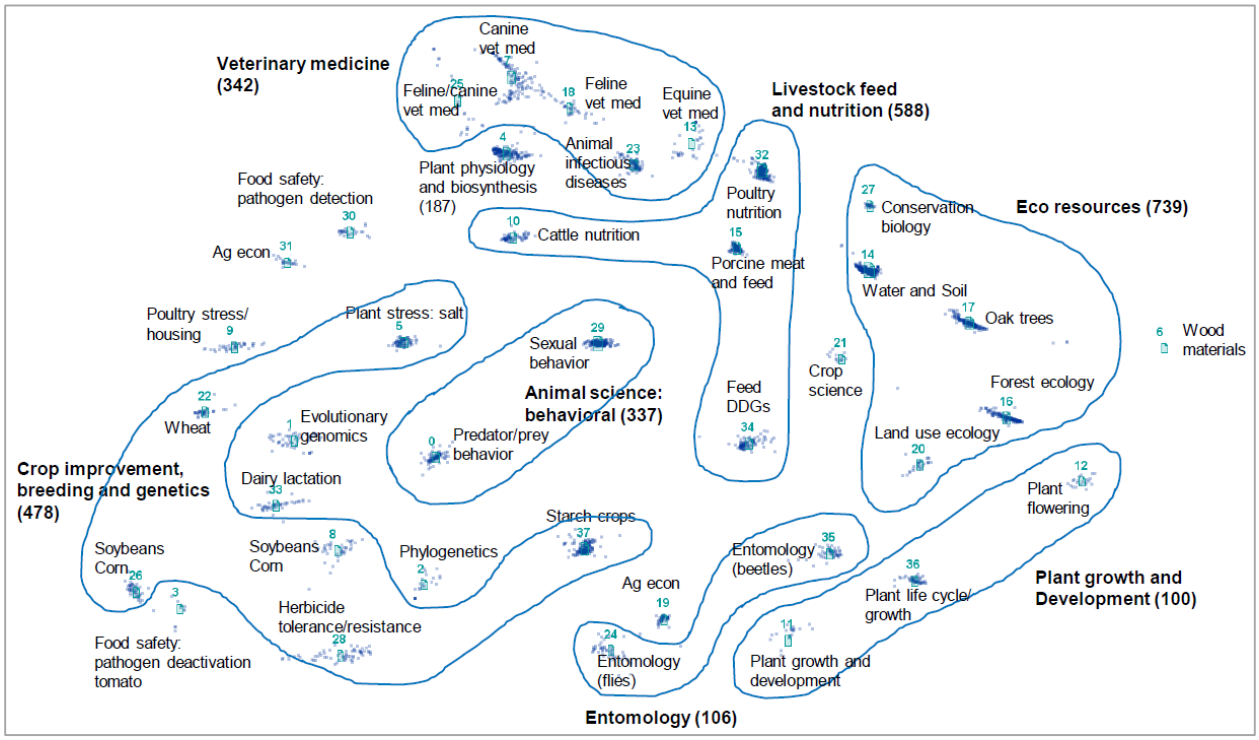


Figure 7. OmniViz Thematic Clustering of Indiana Agbioscience Publications 2009–2014 (June). Battelle's Interpretation of MetaClusters and Apparent Thematic Clustering

[14] Source: Thomson Reuters Current Contents Connect (Web of Science) Database (7/1/2014).

Battelle's interpretation of the OmniViz™ analysis suggests that key themes in Indiana's published agbioscience research center around:

- Veterinary medicine, with companion animal emphasis
- Livestock nutrition/feed products
- Crop improvement in bulk commodity crops (soybeans, corn and wheat)
- Basic work in plant physiology, growth and development
- Behavioral animal sciences
- Research in soils, water, forests and ecological resources
- Niche areas in entomology (especially flies and beetles), tomatoes, food safety, stress tolerance

There is also a significant cross-cutting genomics presence.

Also of note, however, are areas of agbioscience that do not stand out in the publications analysis. Areas such as food science and nutrition, biomass conversion and biobased fuels and chemicals, and agricultural engineering do not produce distinct clusters in Indiana under the OmniViz™ analysis.

Overall, the assessment of published research activity in agbiosciences and associated disciplines in Indiana indicate four major strength foci as illustrated in Figure 8.

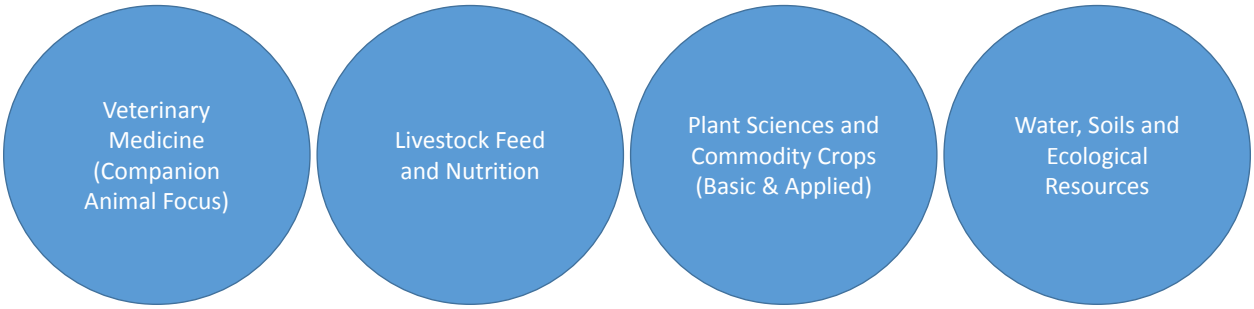


Figure 8. Primary Agbioscience and Related-Field Strength Areas in Indiana Research Publishing

Agbioscience Patent Generation in Indiana

In addition to basic and applied research in agbiosciences, patent data comprise an important measure of agbioscience innovation activity. Battelle analyzed patent data for 2009 through 2013 with the results shown in Table 8. The issued patent counts shown indicate organizational patents with one or more Indiana-resident inventors listed on the patent or patents assigned to an Indiana headquartered agbioscience company.

Table 8. Indiana Agbioscience Patents Issued (2009–2013)

Indiana Based/Indiana Inventor		Indiana Branch and/or Indiana Inventor	
Company Name	**Patents**	**Company Name**	**Patents**
Dow AgroSciences, LLC	365	DuPont Pioneer	225
Mead Johnson Nutrition Company	23	Monsanto Technology LLC	64
CTB, Inc.	17	Radio Systems Corporation	10
Purdue Research Foundation	11	Syngenta Participations AG	9
Elanco	10	M.S. Technologies LLC	9
Agrigenetics, Inc.	5	Limagrain Europe (AgReliant Genetics)	7
Carmel Engineering, Inc.	2	Whirlpool Corporation	5
Innovative Agricultural Concepts, LLC	2	Lucky Litter LLC	5
AccuTemp Products, Inc.	1	Brunob II B.V.	4
American Griddle Corporation	1	BASF Plant Science GmbH	4
Aqua Manna, LLC	1	General Electric Company	4
Bradley Innovation Group, LLC	1	Archer Daniels Midland Company	4
Clabber Girl Corporation	1	Chromatin, Inc.	3
Double C Ranch Supply LLC	1	Kraft Foods Global Brands LLC	3
Farm Innovators, Inc.	1	The Procter & Gamble Company	3
Flavor Burst Co., L.L.P.	1	Tate & Lyle Ingredients Americas LLC	2
Lincoln Foodservice Products LLC	1	Progenetics LLC	2
Mid-West Metal Products Co., Inc.	1	Formax, Inc.	2
NouvEau Inc.	1	Sunbeam Products, Inc.	2
Schutz Brothers Inc.	1	Hill's Pet Nutrition, Inc.	2
Terronics Development Corporation, Inc.	1	Innotek, Inc.	2
Vast Power Portfolio, LLC	1	Xanodyne Pharmaceuticals, Inc.	2
Ziggity Systems, Inc.	1		

Data Source: Thomson Reuters Delphion Patent Analysis

This broad analysis identified 823 issued patents spanning the agricultural, animal health and husbandry, and food processing and preparation equipment space. It is evident from these data that the large plant science-oriented companies (Dow AgroSciences, DuPont Pioneer and Monsanto) are the dominant generators of Indiana-related patents—with these three companies having 654 (or 79 percent) of the patents identified. Other holders of Indiana patents add to this concentration in plant/crop sciences with Syngenta (nine patents), Limagrain (seven patents), Agrigenetics (five patents) and BASF Plant Science (four patents). It should be noted that companies not headquartered in Indiana (such as Monsanto) are included because the inventor of patents they own is/was located in Indiana. For example, a patented innovation may be developed by a faculty member at Purdue, or at a small biotech firm, and then licensed

to Monsanto or another out-of-state entity. In the agricultural and processing equipment sector, CTB is a significant innovator as measured by patents (with 17), while in the food science and nutrition space Mead Johnson Nutrition is an active innovator with 24 patents. Additionally, Purdue University also was the direct assignee of 11 agbioscience-related patents from 2009-2013.

Graduate Output in Agbioscience and Associated Disciplines in Indiana

For an individual economic sector to thrive it must have access to a skilled and appropriately educated workforce. For the agbioscience industry, given the heavy emphasis on science, technology and engineering disciplines, the output of bachelor's and graduate degree recipients in the state is particularly important.

To provide an overview of Indiana graduate output in relevant disciplines, Battelle accessed data from the National Center for Education Statistics IPEDS database and used an occupation to degrees crosswalk developed by the National Crosswalk Service Center in Iowa. Indiana produces approximately 400 graduates annually with degrees related to innovative agbioscience and associated disciplines, with approximately ten percent of these being doctoral degrees (see Table 9).

Table 9. Graduate Output of Indiana Universities and Colleges in Fields Related to Innovative Agbiosciences (2012)

College/ University Degree Fields	IN Graduates (Bachelor's & Higher), 2012	IN Doctorate Degrees, 2012
Key Degree Fields for Primary Agricultural Innovation Related Occupations		
Animal Sciences, General	142	6
Agricultural Engineering	87	14
Horticultural Science	32	4
Food Technology and Processing	31	0
Agronomy and Crop Science	29	0
Animal Physiology	19	0
Food Science	16	10
Entomology	14	1
Soil Science and Agronomy, General	12	2
Agriculture, General	6	0
Zoology/Animal Biology	2	0
Agroecology and Sustainable Agriculture	1	0
Horse Husbandry/Equine Science and Management	1	0
Total	**392**	**37**

Indiana's Workforce in Agbiosciences as Defined by Occupation Groups

The U.S. Bureau of Labor Statistics provides occupations data through the Occupational Employment Statistics Program. Battelle divided occupations into two broad macro-categories: primary agricultural innovation related occupations and secondary agricultural innovation related occupations with the latter comprising some disciplines that may contain ag-related practitioners, but may also contain practitioners in life science areas unrelated to agricultural activity. These very specific "innovation-oriented" occupations and employment account for a relatively small share of the state's total agbioscience employment of nearly 134,000 workers. The data show the presence of various agbioscience-related occupational groupings by raw count and against national normative levels using a location quotient analysis.

Table 10. Indiana's Agbioscience Innovation Related Occupational Employment (2012)

Occupational Groups	IN Employment, 2012	IN Location Quotient, 2012
Primary Agricultural Innovation Related Occupations		
Agricultural and food science technicians	400	1.01
Soil and plant scientists	210	0.78
Agricultural inspectors	210	0.72
Food scientists and technologists	170	0.58
Agricultural engineers	90	**1.69**
Animal breeders	40	**1.27**
Animal scientists	30	0.64
Primary Occupations Subtotal	**1,150**	**0.83**
Secondary Agricultural Innovation Related Occupations		
Biological technicians	1,600	1.02
Veterinarians	1,170	0.97
Biochemists and biophysicists	400	0.70
Microbiologists	390	**1.12**
Conservation scientists	240	0.60
Zoologists and wildlife biologists	120	0.30
Foresters	90	0.44
Secondary Occupations Subtotal	**4,010**	**0.60**

As Table 10 illustrates, in the "primary agricultural innovation related occupations" there are a total of 1,150 persons employed in these occupational categories and that, overall, Indiana is not specialized in this occupational macro classification (LQ of 0.83). Indiana is specialized, however, in two of the primary occupational sub-groups—agricultural engineers (LQ = 1.69) and animal breeders (LQ 1.27). In the secondary occupations macro category, Indiana only shows a moderate specialization in one sub-group, microbiologists, with an LQ of 1.12.

Case Studies: Purdue University

Overview

Founded in 1869, and named after benefactor John Purdue, Purdue University is one of the nation's elite land-grant universities. Established under the Morrill Land Grant Act of 1862, Purdue University is a public institution and leading research university, classified under the Carnegie system as a "research university with very high research activity."

Purdue University has a substantial track record in contributions to Indiana, the nation, and the world across agricultural and engineering related disciplines. Responding to both global needs for food security, and the need of Indiana to sustain an innovative, state-of-the-art, value-added agricultural industry, Purdue has demonstrated a large-scale, sustained commitment to applying research and knowledge in science, social sciences, economics and business studies, engineering and other disciplinary fields to advancing agbioscience research and sustaining agbioscience-based economic, technological, and social development.

Purdue's excellence in the agbiosciences is well-recognized and celebrated, with faculty being members of the National Academy of Sciences and two faculty recipients of the World Food Prize (Dr. Philip Nelson in 2007, and Dr. Gebisa Ejeta in 2009). Purdue's commitment to agbioscience research results in a substantial base of activity. Indeed, in 2013, the combined research expenditures of the College of Agriculture, the Experiment Station and Extension research system at Purdue totaled over $120 million. The basic through applied agbioscience research continuum at Purdue is supported by a robust base of specialized resources and infrastructure, with basic and applied research facilities in West Lafayette supported by 14,697 acres of Purdue University agricultural land distributed across the state to facilitate research and field trial activity, and Purdue Extension reaching all 92 Indiana counties in provision of research-based education.

Areas of Excellence: Purdue at the Forefront of Modern Agbioscience R&D

Given the diversity of Purdue's agbioscience and associated research activity, it is difficult to do justice to the full suite of programs and initiatives (although the OmniViz analysis shown in this report does primarily cover research clusters pertaining to Purdue). However, some particularly well-resourced and influential programs serve to highlight the breadth and depth of Purdue in agricultural, food, life, and natural resource sciences:

- **The Plant Sciences Research and Education Pipeline** was launched in the fall of 2013. Under this pipeline program Purdue has committed more than $20 million focused on building and sustaining Purdue's position as a world leader in understanding the most basic elements of plant biology, translating those discoveries to commercially important crops, assessing the performance of these new developments in the field, and moving these improved plants and products through to commercialization. The Plant Sciences Research and Education Pipeline initiative has four components:
  - ***Center for Molecular Agriculture:*** Investments in fundamental research that allow Purdue to develop the technology to customize plants to meet emerging needs both locally and across the globe.
  - ***Plant Genome Engineering Facility:*** A genome engineering lab bridging the gap between identification of valuable genes and their commercialization.
  - ***Automated Field Phenotyping Laboratory:*** Investment in new technology to facilitate billions of field measurements for detailed assessment of important traits such as canopy development, leaf area index, height, photosynthetic activity, etc., that are important for both research and commercialization.
  - ***Plant Commercialization Incubator Facility:*** For field trials and testing leading to licensing and commercialization in the plant sciences or related areas to move new innovations to market.

The Plant Sciences Research and Education Pipeline engages directly with Indiana's cluster of businesses operating in the plant sciences sector in research, but also provides graduates with technological and analytical skills, and leadership and team work skills, needed to fill important positions in Indiana's agbioscience industry.

- **The Center for Food Safety Engineering** develops new knowledge, technologies, and systems to prevent or detect microbial contamination of foods. It is unique in its multidisciplinary approach to food safety and, in particular, includes a strong engineering focus to food safety issues. The center was established in 2000 as a partnership with the US Department of Agriculture-Agricultural Research Service (USDA-ARS) Eastern Regional Research Center. Engineers and food scientists work together on biological target separation and concentration; and developing different detection platform systems, including biosensor development, optical biosensors, cell-based biosensors, infrared spectroscopy (including Fourier transform infrared spectroscopy), polymerase chain reactions, impedance-based microbiology, scanning microscopy, and bioreporter-based chemical sensors.
- **The Purdue Crop Diagnostic Training and Research Center** is known across the Midwest for its hands-on approach to teaching the art and science of accurately diagnosing agricultural crop problems. The Center, established in 1985, is designed to provide informative topics in a real-world environment, where agriculturists can sharpen their crop-problem troubleshooting skills and evaluate new and alternative management strategies.
- **The Whistler Center for Carbohydrate Research** provides world-class excellence in focused areas of carbohydrate research, analytical services, and education. It works in partnership with companies to extend uses of carbohydrates, hydrocolloids in general, other biopolymers, and cereals. The Center's research focuses on fundamental investigations of structure-function relationships of carbohydrates and other biopolymers as related to practical uses.
- **The Center for Animal Welfare Science** is a good example of Purdue's expertise in facilitating cross-disciplinary and cross-college research, teaching and outreach teams. In this instance the focus is on addressing contentious social issues in animal behavior and welfare; promoting and exploring the broad effects of the human-animal bond; and bridging the rural-urban divide on understanding animals and their evolving roles in society.

Specific Initiatives Supporting the "Business of Agriculture" in Indiana

Purdue has developed several dedicated programs and initiatives focused on delivering research-based solutions and a highly skilled workforce who understand the business of agriculture and specialized agriculture-based value-chains. For example:

- **The Purdue University Center for Food and Agricultural Business**, a leader among educational providers in the food and agribusiness sectors, has designed and delivered managerial education since 1986. Housed within the Department of Agricultural Economics, the Center's faculty and staff develop and execute relevant programs that address the distinctly different needs of managing in today's volatile business environment. While the courses cover many topic areas, particular emphasis is placed on sales and marketing, agribusiness management, and international development and trade. More than 100 days of programming are offered annually.
- **Global Trade Analysis Project (GTAP)** is a global network of researchers and policy makers conducting quantitative analysis of international policy issues. GTAP's goal is to improve the quality of quantitative analysis of global economic issues within an economy-wide framework. It was founded in 1992 in the Department of Agricultural Economics. The centerpiece of the Global Trade Analysis Project is a global database describing bilateral trade patterns, production, consumption, and intermediate use of commodities and services.

Specialized Infrastructure and Assets at Purdue Dedicated to Advancing Agbioscience

Modern agbioscience, as is the case with most areas of life-science inquiry, requires specialized infrastructure, equipment, and support systems to sustain advancements. Research, for example, may require specialized environmentally controlled growth chambers and greenhouse facilities, advanced bio-containment facilities (needed when researching plant or livestock diseases, insect pests, etc.), genomics and other advanced molecular analysis facilities, and pilot plant facilities for evaluating new processing technologies and investigating scale-up potential of innovations. At Purdue University, a series of high-commitment investments have been made to secure the university's position in advanced agbioscience R&D and to facilitate collaborative R&D with industry and government partners. Some examples include:

- **The Horticulture Plant Growth Facility**. Opened in 1998, this facility includes 25 greenhouse rooms totaling 34,800 sq. ft., two air-conditioned growth rooms, 17 growth chambers, five walk-in coolers, a tissue culture laboratory, three teaching laboratories and 4,500 sq. ft. of headhouse space for offices, work space and storage.
- **The Agronomy Center for Research and Education (ACRE)** is a 1,134-acre farm facility close to Purdue's main campus. Ongoing studies range from basic to applied research, including plant breeding and genetics, crop production and soil tillage management, plant physiology, soil fertility, weed control, disease and insect resistance and control, and variety performance evaluation for corn, soybeans, small grains, sorghum, and alfalfa.
- **The Life Science Microscopy Facility (LSMF)** supports research on microscopic and submicroscopic structure of biological and physical systems. Technology in the LSMF provides capabilities for transmission electron microscopy, scanning electron microscopy, and computer-based image analysis. Equipment is available for cryo sample preparation (high-pressure freezing and freeze substitution), ultramicrotomy, critical point drying, vacuum evaporation, sputter coating, digital printing, and histological and cytological specimen preparation.
- **The Animal Sciences Research and Education Center (ASREC)** provides animals, facilities, technical assistance, and labor to conduct research, provide instruction, and assist in Extension educational activities. Research trials vary from basic to applied and involve many disciplines—nutrition, physiology, behavior, genetics, reproduction, animal health, and product quality. Faculty use the Research and Education Center to teach several Animal Sciences courses and to help provide hands-on experience for students. ASREC consists of 1,515 contiguous acres of highly productive prairie soils and is located ten miles northwest of the Purdue campus.
- **Automated Phenotyping Facility** is being built at ACRE that (will be completed by 2016) to advance research in plant phenotyping. It will provide space for phenomics tools and sensor development, plant analysis, seed treatment, threshing and cleaning, and a student innovation hub for interdisciplinary research in the plant sciences.

Also of note is the considerable investment made by Purdue in the development of **Discovery Park**, which is Purdue's hub for interdisciplinary and translational research, conceived as a place where scholars from all disciplines work together to define new areas of research and solve grand challenges. It provides laboratory space and instrumentation for nanotechnology and life science research in a cluster of seven buildings. Faculty and students work on topics related to alternative energy, climate change, soil contamination, and molecular biology. Discovery Park is home to several centers and institutes, including the Center for Global Food Security; C3Bio – Center for Direct Catalytic Conversion of Biomass to Biofuels; Energy Center; Purdue Climate Change Center; Bindley BioScience Center; Birck Nanotechnology Center; Center for the Environment; and the Burton D. Morgan Entrepreneurship Center.

Purdue University as a Collaborative Hub for Agbioscience Industry

Making a difference in agriculture and assuring that agriculture meets its commitment to solving global grand challenges mandates that new agricultural innovations are diffused, manufactured, or introduced to the marketplace. While Purdue Extension plays a critically important role in diffusing knowledge and know-how, the university also sustains intensive relationships with agbioscience businesses, commodity groups, and entrepreneurs to assure innovations are advanced to market. While commercial- and applications-oriented work takes place across all agbioscience and related disciplines at Purdue, some examples serve to highlight the scope of engagement:

- The Whistler Center for Carbohydrate Research works in partnership with companies to extend uses of carbohydrates, hydrocolloids in general, other biopolymers, and cereals. Partner companies include Dow AgroSciences, Kraft, Cargill, Tate and Lyle, ConAgra Foods, General Mills, Pepsico, and others.
- Purdue and Indiana-based Dow AgroSciences have a long-standing partnership working on research on plant traits as well as various chemicals used in agriculture. The Dow AgroSciences Seed Quality Control Lab, located in the Purdue Research Park, occupies 35,000 square feet and supports 16 full-time positions and 32 temporary jobs. The company also operates another research facility and a greenhouse in the Purdue Research Park.
- Purdue and Elanco have a strong working relationship in the animal sciences area related to animal nutrition. Purdue Agriculture has also worked with Elanco on projects related to Heifer International.
- The Indiana Soybean Alliance and Indiana Corn Marketing Program provide funding for applied research and a student innovation contest for new uses for soybeans. Often, Purdue and the commodity groups have representatives on each other's advisory boards.

Purdue is also actively engaged in the direct commercialization of agbioscience innovations. A number of entrepreneurial, fast-growth agbioscience companies have their roots in Purdue research and ongoing relationships. Some examples include:

- Nutrabiotix, Inc. is an Indiana knowledge-based research firm driven by a dynamic collaboration between scientists housed at Purdue Research Park, Purdue University, and Rush University Medical Center. The firm is committed to the mission of improving the digestive health and quality of life through scientifically and clinically tested products that address the specific nutritional needs of patients under a physician's care. This commercialization is as a result of Distinguished Professor of Food Science Bruce Hamaker.
- Tymora Analytical Operations commercializes work by biochemistry professor W. Andy Tao and is located in the Purdue Research Park. The company provides novel research products focusing on phosphorylated proteins and reagents to research and development organizations within the life sciences market.

The Purdue Research Park network is a particularly robust platform for supporting Indiana life science business development and the development of other sectors. It has four locations in Indiana, and 236 companies with more than 4,200 jobs. With more than half a million square feet dedicated to incubation, it is the largest university-affiliated incubation park complex in the country.

Chapter 4. Agbioscience Innovation in Indiana

Innovative Agbioscience Drivers in Indiana

Indiana's Food and Agriculture Innovation Initiative (IFAII), as its name implies, is focused on furthering the development of the agbioscience innovation economy in the State of Indiana. As a technology-based economic development effort, the Initiative is working to document relevant capacities in Indiana and the R&D networks impacting agbioscience innovation in the state. Initial plans for the Initiative are to use information on the innovative agbioscience sector in Indiana to "build awareness of the industry's ingenuity and value through branding and targeted promotion of Indiana's food and agriculture innovation landscape, expand collaboration among key stakeholders in strategic areas such as health and nutrition and agricultural productivity, and support the formation of new innovative companies in Indiana."[15]

A key first step for the Initiative is to develop a baseline understanding of the current status of the agbioscience innovation landscape in Indiana. As Chapter 2 indicated, the state enjoys a diverse agbiosciences profile, and has been experiencing growth across major agbioscience subsectors. As Chapter 3 indicated, the state also enjoys an agbioscience research enterprise base that is both broad in terms of its areas of interest, but also nationally recognized for its concentration and expertise in select categories. However, a high-level overview of Indiana agriculture and agbioscience base needs to be supplemented by a micro analysis of specific areas where agbioscience innovation activity is occurring. To this end, the Battelle TPP project team examined a series of data sources in order to identify innovative companies and areas of agbioscience R&D occurring in the state. This work involved examination of scientific and academic papers produced by Indiana-based researchers, patents assigned to Indiana inventors and/or Indiana-based companies, Small Business Innovation Research (SBIR) and other early-stage innovative company financial awards, and identification of individual companies in Indiana classified within agbioscience subsectors likely to comprise significant innovation activity.

Battelle, in collaboration with CICP and IFAII also worked to identify specific companies and operating entities in Indiana that may be defined as significant participants in innovative agbioscience activity. A total of 93 innovative agbioscience companies were identified in the state, differing in size from large multinational corporations (such as Dow AgroSciences with 1,800 employees) to small start-ups and entrepreneurial companies (such as Spensa Technologies with 12 employees). Upon closer examination of the companies in the innovative agbioscience space, they were able to be broadly segmented into six principal "Innovation Sectors" (Figure 9). These sectors, while influenced by industry segment/NAICS codes, cut across the previous structure to shed light on focused areas of agbioscience innovation in the state. The analysis was built around a "from the ground-up" database of specific companies and operating entities in Indiana developed by Battelle, CICP, and IFAII.

[15] http://www.icemiller.com/ice-on-fire-insights/news/ice-miller%E2%80%99s-bechdol-plays-key-role-in-indiana-foo/#sthash.kcosBJ0N.dpuf.

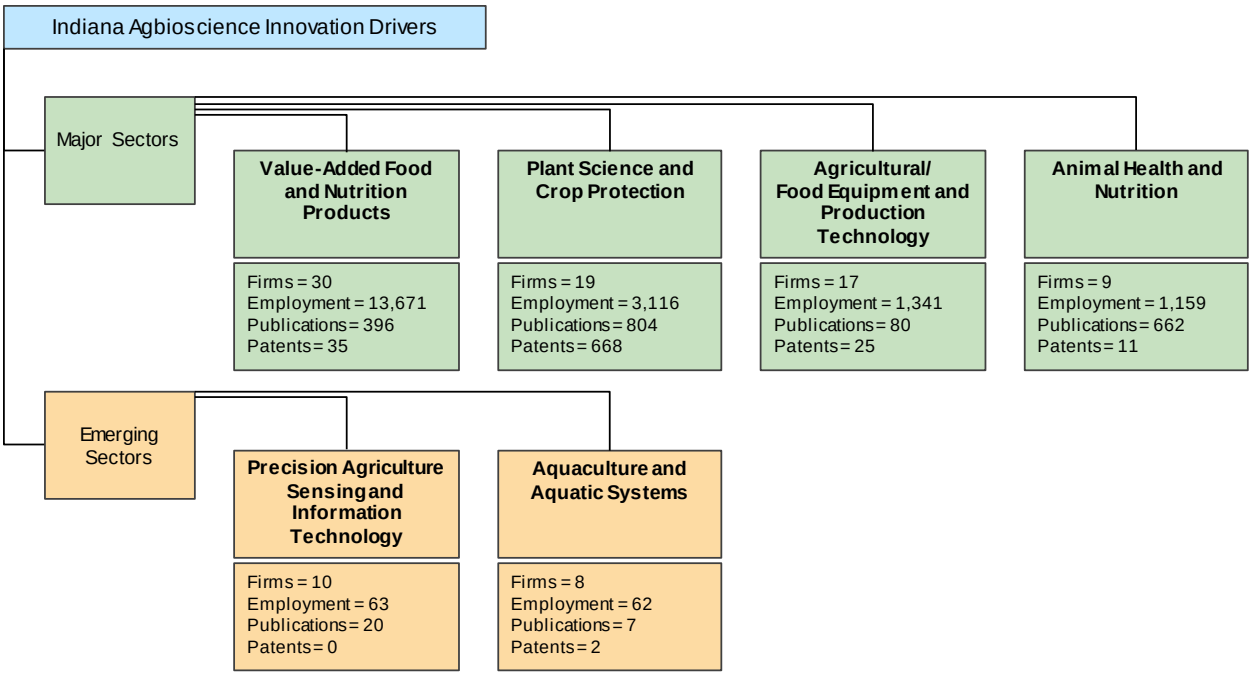


Figure 9: Six Identified Innovative Agbioscience Sectors in Indiana

Each of the innovation driver areas contain multiple operating companies in Indiana. Four of these stand out as major sectors, with employment ranging from 1,159 in Animal Health and Nutrition to a high of 13,671 in Value-Added Food and Nutrition Products. Two emerging sectors are also evident, comprising much smaller levels of employment, but nonetheless representing readily identifiable clusters based on the companies operating in these spaces. Each of the major and emerging sectors is discussed in detail in the sections that follow.

Value-Added Food and Nutrition Products

What Does This Sector Do?

Businesses and innovators in this sector work to add value to basic agricultural commodities by changing or transforming a product from its original state to a more valuable, further-processed state. Many raw commodities have intrinsic value in their original state. For example, field corn grown, harvested and stored on a farm and then fed to livestock on that farm has value. In fact, value usually is added by feeding it to an animal, which transforms the corn into animal protein or meat. In this sector, however, the focus is on downstream, post farm-gate processing of agricultural output into value-added food, nutrition and health products, such as processing wheat into flour, soybeans and milk whey into infant formula, and tomatoes into tomato paste.

It is important to identify the value-added activities that support the necessary investment in research, processing, and marketing. The application of biotechnology, the engineering of food from raw products to consumers and the restructuring of the distribution system to and from the producer all provide opportunities for adding value. For the purposes of this study, the value-added food and nutrition products innovation sector includes organizations engaged in significant food processing activities and other value-added food products.

Why Is This An Opportunity for Indiana?

Currently, there are 30 firms identified in Indiana as engaged in value-added food and nutrition products with a significant employment base of 13,671. Example firms include: ADM; AmeriQual; Artemis International; Cargill; Clabber Girl; Farbest Foods; Ingredion; Maple Leaf Farms; Mead Johnson; Red Gold; Tate & Lyle; and Tyson.

Around the globe, traditional food processing and manufacturing companies are increasingly entering the value-added food and health product market (partly to compensate for the lower margins being realized in the traditional food industry). For instance, while the nutraceutical market is comparatively small compared to the traditional food market, it offers the opportunity for higher profit margins. Retail prices for such products are typically 25 percent to 500 percent above comparable conventional foods as consumers are willing to pay more for additional benefits.[16] Large beverage giants, experiencing a continuous drop in sales of carbonated drinks over the past several years, are entering the functional beverage segment with noncarbonated sports and energy drinks. The functional food products market opportunities are more varied, with analysts seeing large untapped segments such as meat and flour, while confectionery, breads, and snacks represent more mature markets globally.[17] Overall, the United States is leading the global nutraceuticals market with more than 33.1 percent of the market share in 2010, and this market is anticipated to grow at a 6.5 percent compound annual growth rate (CAGR) from 2011 to 2016.[18]

Food manufacturers, already under intense competitive pressure within their historic product lines, are looking at the functional food, beverage, and supplement market for help. Though the value-added food and health product industry is less than ten percent of the total food industry, the market offers significant growth opportunities and wider profit margins. Overall, the increasing effectiveness of the new products entering the market in terms of satisfying health claims, along with growing consumer health awareness, and the promise of higher profit margins is luring almost all of the major multi-national corporations into the market.

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[16] BCC Research. Nutraceuticals: Global markets and Processing Technologies. July 2011.

[17] Ibid.

[18] Ibid.

One of the reasons for this growing market is the fact that an increasing number of consumers are focusing on consuming functional foods and beverages and nutritional supplements as a means to maintain health and wellness. Value-added food and health products provide a potential means for consumers to reduce out-of-pocket costs for primary medical services and prescription drugs, as well as live a longer and healthier life. Moving forward, the market is expected to continue to grow at a strong rate for three primary reasons:

- The elderly population is expanding: More than one billion people globally will be over the age of 50 by 2015; this group is likely to experience one or more chronic age-related disease and seek some form of treatment through nutraceutical products. Longer life expectancies will also increase overall spending for these consumers.
- Young consumers' focus on health: Increased media attention and the increase of available online information is raising health awareness for the young. Increased awareness creates greater concern, which leads to purchase decisions. The recent uncertainty related to the future of the U.S. health care system has also motivated consumers to engage in preventative health care.
- Obesity epidemic: The World Health Organization (WHO) reports that more than 500 million adults globally are obese and an additional 1.0 billion are overweight. Excess weight is the prime cause of hypertension and cardiovascular disease, along with many other conditions. These specific diseases are the leading causes of death among adult populations. Both excess weight and its associated disease states can be treated with nutraceutical products.

Interestingly, growth in the value-added food and health product market has implications for the flavors and flavor enhancers market due to their ability to mask the sometimes unpleasant taste of functional additives. Demand for flavors and flavor enhancers totaled $2.5 billion in 2010 based on advances of 3.6 percent per year[19], and is anticipated to grow at a steady state for the foreseeable future. More than 1,500 different flavoring materials are used by the food and beverage industry, and the final formulation of a flavor for use in an individual product may require more than 100 components.

Using Indiana's agricultural products in the production of value-added food products, advanced/functional foods, and as the basis for the extraction of functional phytochemicals/nutrients for health products represent potential pathways to increasing the value of Indiana's commodities and specialty agricultural products.

Recent Innovation Performance

Research Publications (2009-6/2014)	396 publications. Key disciplines include food science, agricultural chemistry, nutrition & metabolism, and agriculture/agronomy. Dow AgroSciences – 18 publications in this sector (114 total) Mead Johnson Nutrition – 13 publications in this sector (14 total) Elanco – 11 publications in this sector (84 total)
Patents (2009-2013)	35 patents Mead Johnson Nutrition – 23 patents Purdue University – 3 patents
Innovation Resources and Capital (2003-To Date)	
➢ USDA Funded Research (non-SBIR)	19 Awards; $5,400,026

[19] Freedonia. *Food and Beverage Additives.* August, 2011.

➢ SBIR Awards	5 Awards; $722,046
➢ Venture Capital	0 Investments
➢ 21st Century Fund	3 Investments totaling $233,705 to: This Old Farm, Hawthorne Mushrooms, and Rubicon Foods

Indiana companies have a strong base of innovation within the value-added food and nutrition products. Companies such as Mead Johnson Nutrition are actively engaged in research and commercialization of new products. Indiana has also received innovation capital resources from a wide variety of sources, including indigenous sources of funding. However, it is somewhat troubling that there has been no venture capital investments over the time period. With Indiana's strong agricultural base, this could be an area to explore in the future to help foster the growth of innovative companies.

Companies that are Actively Involved with this Innovation Sector

Company Name	Innovation Area Descriptions
ADM	Archer Daniels Midland Company, as one of the world's leading agricultural processors, converts corn, grain and other agricultural resources into products for the industrial, animal feed, energy and food and beverage markets.
AmeriQual Group, LLC	AmeriQual is a leader in shelf-stable food production processes and products, including thermal-processed pouch products for the United States Department of Defense, Meals Ready-to-Eat (MRE) and Humanitarian Daily Rations (HDR). The company also produces products to serve large groups, including flexible food pouches, trays and other product storage and disposal items that extend the shelf life of food.
Artemis International, Inc.	Artemis International, Inc. provides berry-based products for the food, beverage and dietary supplement industries, including specialty concentrates, fibers, powders, dried berries, and supplement formulations.
Cargill	Cargill is one of the world's largest, privately-owned businesses, providing food, agricultural, risk management, financial, and industrial products and services around the globe.
ChocoFinesse	ChocoFinesse is a food research organization whose core product is Epogee, a modified fat with a low amount of calories that can be used as a fat replacement in other foods.
Clabber Girl Corporation	Clabber Girl Corporation, an expert in chemical leavening, is a premier provider of ingredient solutions across a variety of industrial markets, focused on building market share around its encapsulation expertise in food and animal nutrition.
Creighton Brothers	Creighton Brothers is a major producer and processor of eggs.
Fair Oaks Farms	Fair Oaks Farms is a fully sustainable dairy and hog farm that also provides tours and interactive exhibits.
Farbest Foods, Inc.	Farbest Foods is one of the largest turkey companies in the United States and supplies leading U.S. food producers with fresh and frozen turkey products.
Hawthorne Mushrooms, Inc.	Hawthorne Mushrooms, Inc. is a producer and supplier of oyster mushrooms and shitake mushrooms.
Husk LLC	Husk LLC is a local food system in Indiana—farms, processing, distribution, and retail grocery—which provides year-round access to local Indiana foods.

Company Name	Innovation Area Descriptions
Indiana Packers Corporation	Indiana Packers Corporation is a pork production and packaging company.
Ingredion, Inc.	Ingredion, Inc. is a leading ingredient provider to the food, beverage, pharmaceutical and brewing industries specializing in nature-based sweeteners, starches, and nutrition ingredients.
JBS United	JBS United is a global leader in animal health and nutrition providing research-based products, swine production and management services, and grain storage facilities.
Maple Leaf Farms	Maple Leaf Farms provides production of duck and chicken meat for supply to the foodservice and retail industries.
Mead Johnson Nutrition Company	Mead Johnson Nutrition Company is a producer of innovative nutrition products for infants, children and adults, as well as pharmaceuticals and enteral and parenteral nutrition products.
Midwest Poultry Services	Midwest Poultry Services is a large-scale egg production company.
Morgan Foods, Inc.	Morgan Foods engages primarily in the development and production of canned store brand food items.
Nestle	Nestle is one of the world's leading producers of various food products including coffee, chocolate, bottled water, and ice cream and other frozen foods.
NouvEau Inc.	NouvEau Inc. is a patent and intellectual property holding company for license of the manufacture and branding of a luxury line of non-alcoholic beverages.
Nutrabiotix, Inc.	Nutrabiotix is a research firm focused on improving the digestive health and quality of life of medical patients through scientifically and clinically tested products that address the specific nutritional needs of patients under a physician's care.
Phytoption, LLC	Phytoption, LLC is a producer of all natural food coloring, and also provides technical services for product formulation and processing design.
Red Gold	Red Gold produces a variety of canned tomato products for the foodservice industry.
Rose Acre Farms	Rose Acre Farms is a leading egg producer, supplying a variety of eggs and egg products.
Rubicon Foods, LLC	Rubicon Foods, LLC specializes in pureed foods and food mixes for medical-related/nursing home diets.
Tate & Lyle	Tate & Lyle is a multinational starch manufacturer and wet corn mill that also produces animal feed and ingredients for the food and beverage industries.
This Old Farm	This Old Farm is a supplier of local, sustainably grown food products for clients ranging from schools to wholesale commercial entities.
Tyson Foods, Inc.	Tyson Foods, Inc.'s Indiana operations include a feed mill, poultry and other meat processing plants, and a corn and flour tortilla manufacturing center.
Wabash Valley Produce, Inc.	Wabash Valley Produce is an egg and turkey producer and wholesaler.
Weaver Popcorn Company	Weaver Popcorn is a producer of microwave and concession popcorn.

Case Studies: Mead Johnson Nutrition

Company Overview

Decades of research have proven that children who are well-nourished from infancy are more likely to lead healthier, more productive lives. To this end, Mead Johnson Nutrition's mission is to nourish the world's children for the best start in life by developing safe, high quality, innovative products to meet the nutritional needs of infants and children around the world.

The company was founded in 1905 by Edward Mead Johnson, a father whose own son faced life-threatening feeding difficulties. Today, Mead Johnson is the only global company exclusively focused on pediatric nutrition, and is recognized as a world leader with more than 70 products in over 50 countries. With sales totaling $4.2 billion in 2013, Mead Johnson employs approximately 7,000 individuals globally. Nearly 1,000 of those employees are located in Evansville, Indiana, staffing the company's Global Operations Center and the first-ever technology and learning center of the Mead Johnson Pediatric Nutrition Institute, as well as major manufacturing operations and various administrative functions.

The Mead Johnson Pediatric Nutrition Institute or MJPNI opened in 2010. It represents a $26-million investment and is capable of matching manufacturing processes and testing new equipment to make product development more efficient, and increasing the speed of innovation. The centerpiece of the 43,000 square-foot facility is a four-story pilot production spray dryer, allowing for faster evaluation of test products.

How Innovation has Driven Growth

Mead Johnson's research and development function is supported by an annual budget of approximately $100 million. Beyond the company's 300-plus in-house scientific and technical experts, the team includes a virtual, global network of leading scientific experts, research initiatives and data sources. A flagship of this effort is the MJPNI. Through ongoing research, clinical trials, consumer testing, and process engineering, the Institute connects innovative scientific technology and research with cutting-edge manufacturing, as well as advancing the overall understanding and body of knowledge regarding pediatric nutrition and its connection to long-term well-being. Through this commitment to innovation, the company has been able to grow and gain market share through unique product segments focused on early brain development, healthy growth, and immune support.

Collaborations

Mead Johnson fosters and develops strong relationships with organizations in academia, public health, pediatric medicine, dietetics and child care to collaborate on initiatives that positively impact the well-being of children. At any given time, the company has more than 50 clinical trials being conducted around the world, as well as an equivalent number of research projects with global partners on such areas as brain development and nutrition development in infants. Specific to Indiana, Mead Johnson has strong collaborative research relationships with Purdue's Nutrition and Food Science Department, as well as with the Indiana University School of Medicine focused on the connection between brain development/neurology and human nutrition.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

The region represents the largest concentration of food and nutrition knowledge in the world, with major food companies and leading universities in food science and nutrition located in close proximity.

- As a major logistics hub, the distribution of products can be done with ease and minimal cost.
- State government is considered to be pro-business with competitive tax rates.

Case Studies: Clabber Girl

Company Overview

Located in Terre Haute, Indiana, Clabber Girl has been a family-owned business focused on building market share around its expertise in chemical leaveners. Today, Clabber Girl prides itself as being the premier provider of ingredient solutions across a variety of industrial markets.

In 1850, Hulman & Company, began as a wholesale grocery business, but quickly expanded into manufacturing a variety of products, including spices, coffees, and baking powder. By 1899, Clabber brand baking powder was introduced, and over the years increased its market presence until it became the nation's number one retail brand of baking powder distributed nationwide and too many international markets.

Clabber Girl Corporation, as a subsidiary of Hulman & Co., continues to expand its product lines and now distributes retail, wholesale and industrial size baking powder products under many different brand names. The business has expanded its foodservice offerings to include baking powder, baking soda, cornstarch, and the Royal brand products which include cheesecakes, puddings and gelatins. Industrial formulations are designed specifically for the demands of modern food manufacturing.

How Innovation has Driven Growth

In 2000, recognizing that 90 percent of Clabber Girl's business was based on retail sales of baking powder—a product whose demand was based on individuals baking from "scratch"—the management team refocused the company's efforts on diversification and the development of innovative solutions for industrial food manufacturers. As a result, Clabber Girl was able to position itself in the market as the "ingredient solutions provider". Through innovations in encapsulation technologies, for example, Clabber Girl was able to solve problems related to frozen batter reaction time, shelf life, and mass production issues.

Today, Clabber Girl is expanding its innovative products into new markets. Specifically, the company's research into encapsulation has revealed attractive opportunities in the animal feed industry. The production process of encapsulated ingredients for animal feed was the same as that for bread and frozen baked goods. For animals, encapsulated ingredients offered a potential to improve digestion, increase nutrient absorption, and reduce the volume of food supplements required to achieve desired biological outcomes.

The company sees encapsulated animal feed ingredients as strategically consistent with its mission of "adding value to the preparation and consumption of food." Animal nutrition solutions from Clabber Girl would enhance the efficiency of global food production.

Collaborations

While Clabber Girl has undertaken significant internal R&D effort to develop and patent its encapsulation technologies, it has also worked closely with Purdue's Food Science experts as well as the Manufacturing Technical Assistance program to conduct testing and provide consultation. The company also works closely with a variety of animal and commodity groups to understand industrial problems for which it can develop ingredient solutions.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- Indiana's cost of business is very competitive;
- Logistics and distribution advantages due to proximity to major markets;
- Quality of workforce; and
- Organizations, such as IFAII, that have been formed to coalesce industrial/research assets to strengthen the industrial base and build critical mass.

Case Studies: Maple Leaf Farms

Company Overview

Maple Leaf Farms, a fourth generation family-owned company headquartered in Leesburg, Indiana, is the leading producer of duck products, supplying retail and foodservice markets throughout the world with innovative value-added foods. Founded in 1958, Maple Leaf Farms began as a small duck operation producing 280,000 ducks its first year. Maple Leaf Farms' commitment to "quality you can count on" fueled its growth, and today the company dominates the North American duck market with innovative, value-added products, producing up to 15 million ducks annually with annual sales of $160 million.

Maple Leaf Farms encompasses a number of vertically integrated operations, including breeding farms, hatcheries, biotech and analytical labs, feather operations, feed mills, primary processing, and value-added processing plants. By paying careful attention to quality at each step of production, its nearly 1,000 employees and more than 150 partner farmers are able to produce the highest quality duck products in the marketplace.

How Innovation has Driven Growth

Maple Leaf Farms is one of only a few fully integrated primary duck breeders worldwide, and conducts extensive research and development in genetics, nutrition, duck health and welfare, and environmental improvement of duck production. As a pioneer in the duck industry, the company is committed to identifying and developing new business opportunities to leverage its integrated duck system technology.

Maple Leaf Farms' unique breeding stock, which is developed through a proprietary pedigreed breeding program, serves as the foundation for the business and provides a unique comparative advantage. In addition to its own internal R&D efforts, the company is also focused on integrating available commercial technologies into its production practices. For example, capitalizing on the company's genetic stock, Maple Leaf Farms works to adopt animal husbandry and feed manufacturing technologies and practices that maximize the genetic potential of the birds. At its food processing plants, the company continually adopts technologies and invests in equipment that allows for the development of new products or packaging or improve on current production practices.

Collaborations

Maple Leaf Farms has a strong collaborative relationship with Purdue University, particularly with the animal science and food science departments within the College of Agriculture. Scientists within both of these departments have provided technical assistance, and the company has directly and indirectly (through the Midwest Poultry Consortium) sponsored poultry science research at the university.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- Favorable business environment as is relates to taxes and regulations;
- Emphasis on fostering a strong agricultural industry; and
- Strong network of world renowned research universities.

Products/Activities Related to Other Innovation Sectors

Maple Leaf Farms' Work in Animal Health and Nutrition

In recent years, Maple Leaf has pursued new markets through the development of animal health and nutrition products and services. Through MLF Biotech, Inc., a division of Maple Leaf Farms, the company specializes in animal health and nutrition by promoting a healthy digestive tract in the animal through the use of probiotics and by protecting it from ingested toxins through toxicity testing services. MLF Biotech is the exclusive provider of ToxiScreen®, which detects the overall toxicity of ingredients, feed and finished food products with a single test.

In addition, through its International Division, Maple Leaf Farms has developed an integrated duck production system, INDUX®, that offers nutrition, diagnostics, research, management and other services to international duck breeding stock customers, through its international division. The INDUX™ System is designed to improve duck health and performance while reducing production costs.

Plant Science and Crop Protection

What Does This Sector Do?

This sector includes organizations and companies engaged in crop improvement and crop protection via the application of plant science, biotechnology, chemistry, and other scientific disciplines. These companies engage in seed genetics and development, crop hybridization, and the development and production of agricultural chemicals (fertilizers, herbicides, pesticides). A key goal of business in this sector is to enhance the productivity of production agriculture through creating crops with higher yields, resistance to stress (such as drought or frost tolerance), and resistance to pests and plant diseases. Enhancements may be generated through traditional breeding/hybridization techniques and advanced genomics technologies. Innovators in this sector may also work to introduce crop varieties with enhanced functional characteristics (nutrition content, color, flavor, shape, downstream processability characteristics, etc.) Chemistry is also an important area of activity in this sector, with companies engaged in developing targeted crop protection chemicals, fertilizers, soil inoculants, and other chemical and biologic inputs to production.

Why Is This An Opportunity for Indiana?

Currently, 19 firms with 3,116 employees are classified into this innovation sector. Example firms include: Agdia; AgReliant Genetics; Beck's Hybrids; Dow AgroSciences; DuPont Pioneer and Remington Seeds.

As Battelle notes in a report for BIO, "with global population increasing rapidly and the vast majority of farmable land already in production, the future of human kind depends on increasing agricultural yields."[20] Further pressure is placed on increasing yields and protecting agricultural production by increasing global purchasing power, which in turn increases the demand for meat—driving demand for livestock feed products. As a result, projections for the plant science and crop protection industry show robust growth rates:

- The global market for agricultural biotech (including transgenic seeds) is expected to reach $24.8 billion by 2017, up from $13.7 billion in 2011 for a CAGR of 11.4 percent with the U.S. market expected to account for approximately 75 percent of the global market.[21]
- The global seed treatment market reached $3.1 billion in 2012 and is expected to grow to nearly $4.8 billion by 2018, a compound annual growth rate (CAGR) of 8.3% for the period of 2013 to 2018.[22]
- The North American seed treatment market is expected to reach $1.5 billion in 2018.

Companies operating in this sector in Indiana report that the state has several advantages as a location for plant science and crop protection operations. The presence of Purdue and other major proximate land-grant universities specializing in commodity crop improvement provide a resource for R&D partnerships and for highly skilled graduates. Indiana's Midwest location also provides a robust setting for field trials, demonstrations and other interactive activities with the farming community.

[20] Battelle and BIO. *Healing, Fueling, Feeding: How Biotechnology is Enriching Your Life. 2012.*
[21] BCC Research, *Agricultural Biotechnology: Emerging Technologies and Global Markets*, *2012*.
[22] BCC Research, *Seed Treatment: Technologies and Global Markets*, *2013*.

Recent Innovation Performance

Research Publications **(2009-6/2014)**	804 publications. Key disciplines include plant sciences, agronomy, entomology, and agricultural chemistry. Dow AgroSciences – 73 publications in this sector (114 total)
Patents **(2009-2013)**	668 patents Dow AgroSciences – 359 total patents (83 with one or more Indiana inventors); DuPont Pioneer – 225 patents; Monsanto – 64 patents AgReliant Genetics (Limagrain) – 7 patents; Agrigenetics (not included in Dow AgroSciences) – 6 patents Purdue University – 7 patents
Innovation Resources and Capital (2003-To Date)	
➢ USDA Funded Research (non-SBIR)	76 Awards; $15,859,819
➢ SBIR Awards	3 Awards; $608,053
➢ Venture Capital	0 Investments
➢ 21st Century Fund	2 Investments totaling $159,219 to: Agri Processing Services and SePRO Corporation

Companies that are Actively Involved with this Innovation Sector

Company Name	Innovation Area Descriptions
A&L Great Lakes Laboratories	A&L Great Lakes Laboratories provides agricultural testing and analytical laboratory services.
Agdia, Inc.	Agdia, Inc. is focused on providing diagnostic tools to assist in the management of plant diseases caused by viruses, bacteria, fungi, and other pathogens.
AgReliant Genetics (Limagrain Europe)	AgReliant Genetics is an innovative seed company focused on crop science and corn hybrids production.
Agri Processing Services, LLC	Agri Processing Services, LLC produces a non-ferric-based compound designed specifically to recover feed grade quality proteins, fats, and carbohydrates from processing and waste water.
Ag Alumni Seed	Ag Alumni Seed is a supplier of high performance popcorn, oat, and soft red winter wheat hybrid seed stock.
Beck's Hybrids	Beck's Hybrids is a family-owned and operated seed company that sells high performing hybrid seeds to improve resilience and yield.
Brodbeck Seeds	Brodbeck Seeds is a supplier of corn, soybean, alfalfa and wheat seeds.
Dow AgroSciences	Dow AgroSciences is a multinational agricultural products/services company focused on increasing crop productivity through higher yields, better varieties, and more targeted pest management, as well as developing innovative chemical and biotechnology solutions to meet the food, feed, and fiber needs of the world.

Company Name	Innovation Area Descriptions
DuPont Pioneer	DuPont Pioneer is a biotech-oriented seed development company that produces seeds and agricultural traits and technologies.
IOM Grain, LLC	IOM Grain produces and distributes non-GMO soybeans and corn to domestic and international food markets.
INCOTEC Field Crops North America (fka Landec Ag, Inc.)	INCOTEC Field Crops North America provides services for seed enhancement, seed coating, pelleting, and genetic and quality analysis of seeds.
Langdon Bros. Seed	Langdon Bros. Seed supplies wheat, oat, soybean, corn and grass seed, as well as clay products for baseball fields.
Lord's Seed	Lord's Seed is a crop production company, producing seed corn, seed soybeans, hay, commercial corn, commercial soybeans, wheat and green beans.
Monsanto	Monsanto is a multinational agricultural company specializing in agricultural biotechnology and chemicals. Products include high-yielding conventional and biotech seeds, crop traits and technologies, and crop protection solutions.
Remington Seeds	Remington Seeds is a seed production company that provides customized seed products to the corn, wheat, and soybean seed industries.
SePRO Corporation	SePRO Corporation develops and manufactures aquatic herbicide products, lawn and turf landscaping products, and greenhouse and nursery products.
Specialty Hybrids/Funk Seed	Specialty Hybrids provides corn, soybean and alfalfa seeds and seed protection products to growers in Indiana, Ohio and Michigan. Funk Seed is a corn and soybean seed producer which also offers crop management services including crop genetics and collection of real time crop data using Unmanned Aerial Vehicles (UAVs).
Trupointe Cooperative, Inc.	Trupointe Cooperative is a farm cooperative owned and operated by farmers that supplies turf, animal feed, grain and propane services.
Vertellus (fka Reilly Industries, Inc.)	Vertellus produces specialty chemicals to be used in markets including agrochemicals, nutrition, pharmaceuticals and agriculture.

Case Studies: Dow AgroSciences

Company Overview

By 2050, the world's food production systems must support an estimated nine billion people, with a shrinking base of agricultural land and limited water resources. Dow AgroSciences is focused on combining the power of science and technology with the "human element" to discover and develop innovative agricultural solutions for a more sustainable world by increasing crop productivity through higher yields, better varieties, and more targeted pest management, as well as developing innovative chemical and biotechnology solutions to meet the food, feed, and fiber needs of the world.

Dow AgroSciences began in the 1950s as the agricultural unit of The Dow Chemical Company. In 1989, The Dow Chemical Company entered a joint venture with the Elanco Plant Sciences business of Eli Lilly and Company, resulting in the formation of DowElanco. In 1997, The Dow Chemical Company acquired 100 percent ownership of the business and renamed it Dow AgroSciences.

Today, Dow AgroSciences administration and R&D activities are headquartered in Indianapolis, the central point of a world-class manufacturing and research and development network with facilities in more than 40 countries and products sold in more than 130 countries. With sales totaling $7.1 billion in 2013, Dow AgroSciences employs more than 8,000 individuals globally, with approximately 1,500 located in Indianapolis.

R&D efforts have also grown on a global scale, with more than 1,800 employees dedicated to R&D ─ about one of every three people in the company. Among the company's most recent expansions was the 2013 introduction of a new, state-of-the-art Biotechnology Research Center on the Indianapolis campus. Dow AgroSciences R&D investments annually equate to approximately ten percent of its sales.

How Innovation has Driven Growth

On average, it takes ten years and an investment of more than $256 million to bring a new agricultural chemical compound to market. Similarly, from gene discovery to commercial launch, the development and registration of a new trait takes more than 13 years and approximately $136 million ─ a cost that is rapidly increasing with the increasing complexity of traits.

With so much on the line, it's critical to be as efficient and effective as possible. Dow AgroSciences has an excellent investment-to-commercialization success rate that focuses on market needs, openness to strategic collaboration, investment in state-of-the-art scientific technologies and a disciplined development process. Dow AgroSciences R&D manages a full pipeline of innovations—with efforts related to discovery and development headquartered in Indiana — with active, successful development programs in agricultural chemicals, biotechnology and germplasm. To facilitate its research, Dow AgroSciences invests in new scientific technologies, such as EXZACT™ Precision Technology, which is a cutting-edge, versatile and robust toolkit for genome modification in plants. The company's focus on a broad range of technologies lets it tailor solutions to a wide variety of applications and geographies.

Within its crop protection platform, Dow AgroSciences has a diverse portfolio of leading-edge insecticide, herbicide, fungicide and fumigant technologies. Research efforts in seeds are focused on increasing yields for growers worldwide by improving genetics and stress tolerance, and helping to ensure effective weed and insect control. New investment in research, in combination with strategic collaborations and acquisitions, is resulting in more productive and resilient crops.

Over the past decade, Dow AgroSciences' crop protection business has nearly doubled in size—delivering very strong return on capital and margin expansion. And it was during this period that the company also established a world-class seeds business. Furthermore, since 2007, the company has increased its priority patent filings by more than 300 percent and has more than 4,000 active patents globally.

Dow AgroSciences continued to grow faster than the market due to its robust pipeline of innovations. A number of key industry-leading technologies position the company for additional near-term growth, including:

- SmartStax® Refuge Advanced® is a blend of 95 percent SmartStax corn seed and five percent refuge seed, allowing farmers to reduce refuge acreage from 20 percent to five percent. SmartStax Refuge Advanced enables more effective resistance management by placing responsibility for refuge implementation on the seed provider instead of the grower.
- Spinosad, first insect management product derived from a natural source. As an insecticide, it's sold under the Dow AgroSciences brand names of Conserve®, Tracer®, Success® and Entrust®, among others. Spinosad products are registered on more than 150 crops in more than 30 countries, and Entrust is one of the mostly widely used products for organically produced crops in the U.S. and in other parts of the world.
- Spinetoram is a semi-synthetic insecticide that provides subtle, but significant, improvements to the highly complex spinosyn pest management technology. Its brand names include Delegate® and Radiant®.
- Isoclast™ active insecticide (named one of the top 100 innovations in 2013 by R&D Magazine for its Transform® and Closer® formulations) represents a new class of chemistry discovered and developed by Dow AgroSciences globally in all major crop groups to protect them from key sap-feeding pests. Isoclast is highly effective and features low use rates and minimal impact on beneficial insects. The product was first introduced to the market in 2013 and allows Dow to compete in a $2 billion market segment for which there is no biotech solution available.

Collaborations

Dow AgroSciences prides itself in creating a culture that fosters strong collaborations and strategic alliances with global industry, academia and government entities for licensing, partnerships or acquisitions to accelerate innovation and advance science in crop protection, plant genetics, biotech and enabling technologies. As a result, Dow AgroSciences leads the industry in proportion of R&D spending with outside collaborators to cultivate innovative ideas and discoveries.

To this end, Dow AgroSciences has multiple ongoing collaboration projects with Purdue University related to plant breeding, seeds and computational services. Through a long-term research agreement put in place many years ago, Dow AgroSciences and Purdue are able to streamline the efficiencies and effectiveness of their collaborations. A formal Collaboration Team, composed of representatives from both organizations, meets quarterly and talks monthly regarding projects and priorities.

In addition, Dow AgroSciences has three facilities within the Purdue Research Park:

- Trait Product Development – developing solutions for crops of interest through early-stage, high-tech research.
- Seed Quality Control Lab –testing and validation center for the seed business to ensure quality of seed products.
- Greenhouse Complex – undertaking reduction to practice work to drive rapid decision making in plant development.

Dow AgroSciences has a number of collaborations with other research institutions in Indiana as well, including working with Butler University on the design of a sustainable condenser, and providing adjunct faculty to Purdue, Butler, Indiana University-Purdue University Indianapolis (IUPUI) and Ivy Tech. The company also recruits from these institutions, as well as other local colleges and universities, for researchers, engineers, MBAs and other skilled positions.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana and the Indianapolis region:

- As a city, Indianapolis is located in one of the United States' most productive farming regions (tenth in national total agricultural production and in the top five for crop production, especially corn and soybeans, which are primary crops for Dow AgroSciences). It also has allowed the company to build upon strategic partnerships with a number of land-grant university research organizations in easily accessible proximity.
- Indiana has positioned itself as a state favorable for the growth and proliferation of life sciences companies and research institutions. Through a number of initiatives, including BioCrossroads, the state actively encourages novel public/private partnerships to advance science and develop scientific resources for the future.
- For employees, Indiana – and Indianapolis in particular – offers an urban setting with affordable living and multiple opportunities for cultural enrichment and community involvement.

Products/Activities Related to Other Innovation Sectors

Dow AgroSciences' Work in Value-Added Food and Nutrition Products:

More than two-thirds of Americans are obese or overweight, prompting the U.S. Department of Agriculture (USDA) to issue dietary guidelines in 2010 that called for a reduction in saturated fat intake, including their replacement with heart-healthy monounsaturated and polyunsaturated fatty acids. Omega-9 Oils, made from Dow AgroSciences' Nexera® canola and sunflower seeds, have zero trans-fat, the lowest amount of saturated fat among oils, and feature more than 70 percent heart-healthy monounsaturated fat. This unique oil profile offers desirable performance attributes for frying and processing food while maintaining a flavor that does not interrupt the natural flavors of the other food ingredients. Versatile in a wide variety of food applications, Omega-9 Oils are healthier alternatives for restaurant use, consumer packaged goods, and food manufacturing. With the wide adoption of Omega-9 Oils in the foodservice industry since 2005, Dow AgroSciences' oils have helped to remove more than 1.5 billion pounds of bad fats from the North American diet.

While canola is primarily grown in Canada, development of the oil takes place on the Indianapolis campus in Dow AgroSciences' labs and culinary research center. Dow AgroSciences' scientists are working both locally and globally to develop a variety of oil compositions to further explore health benefits. In addition, the company's culinary research center is exploring real-world food applications to find the best texture and taste profiles desired by consumers. Dow AgroSciences has worked with hundreds of food marketers to make the switch to Omega-9 Oils, including Indiana-based Weaver Popcorn Company, Inc. (Pop Weaver® popcorn). The company is continuing to develop new Omega-9 and Omega-3 oils in its Indianapolis facilities, as well as enhanced canola meal for better animal feed.

Case Studies: Beck's Hybrids

Company Overview

Beck's Hybrids is a family-owned and operated seed company that sells high performing corn, soybean and wheat seed to farmers in Indiana, Illinois, Ohio, Michigan, Kentucky, Tennessee, Iowa and Missouri.

Early ancestors of the Beck family settled in central Indiana and were farmers. Beck's Hybrids was founded in 1937 when Lawrence Beck and his son Francis each planted three acres of hybrid seed from the Botany Department at Purdue University. From this small plot start Beck's has grown to be the sixth largest seed company in the United States and the only one in the top six that is family-owned. This makes Beck's the largest retail, family-owned seed company in the United States.

Beck's is headquartered in Atlanta, Indiana and all primary business functions are based there. This includes research, sales, marketing, finance, IS/IT, production, and processing activities. Beck's internal R&D is conducted in its biotech building and six greenhouses used for genetic trait introgression work. Beck's has a Foundation Seed facility in nearby Sharpsville for the production and processing of parent seed used by its production department to produce hybrid seed corn.

By offering customers access and choices in traits and elite genetics, the company has averaged double digit percentage growth for well over 20 years. Beck's currently employs 416 full time employees, with over 275 of these employees located in Indiana.

How Innovation has Driven Growth

Beck's Hybrids has one of the largest seed testing and breeding programs in the Eastern Corn Belt. The company's research program focuses on improving germination, emergence, standability, plant health, and yield.

Beck's Hybrids intense multistage testing program allows Beck's to select and develop products that will out-yield the competition and provide a distinct regional advantage. Beck's accomplishes this regional advantage through its replicated testing program and its Choice Trials. The replicated testing program is used to identify products in an early stage that have commercial potential. Then Beck's utilizes its Choice Trials program, which is an on-farm testing program, to test pre-commercial products and identify specifically the best area of adaptation. With Beck's research team intensively characterizing the products at these sites, the highest performing products are identified. Through this model, Beck's opts not to conduct trait discovery research; instead, Beck's has relationships with numerous genetic, trait and technology providers and licenses technologies and then utilizes its biotech building and greenhouses to conduct trait introgression.

Beck's Hybrids corn breeders are also utilizing the latest breeding technologies, including rapid inbred development through the use of high tech methods such as diphaploid breeding, marker assisted backcrossing, and embryo rescue techniques. The company also practices genome-wide selection with a state-of-the-art molecular marker laboratory. Via these innovative methods, Beck's offers farmers numerous seed trait and technology options.

An additional key area of innovation at Beck's has been in the development of seed treatments. All seed corn, soybeans and wheat sold by Beck's is treated with the Escalate™ yield enhancement system. This is a proprietary mix of yield enhancing products that is provided on all Beck's seed. Offering insect protection, improved stands, seedling health and yield, this unique blend is sealed onto each seed using Beck's exclusive polymer.

Collaborations

Farm management is highly complex and farmers do not have time to evaluate every potential procedure or technology. On-farm research is costly, time consuming, and often confusing, and so Beck's has undertaken the job for farmers and developed five farms devoted to Practical Farm Research (PFR) to learn how different management practices and new technologies perform in field environments. Simply put, it is research focused with the farmer in mind. There are approximately 600 acres devoted to conducting over 70 unique studies on the farms located in: Atlanta, Indiana; Downs, Illinois; Neoga, Illinois; Henderson, Kentucky; and London, Ohio. This work is farmer focused and the information is shared with famers free of charge via annual field shows, PFR books, a website, and winter meetings. Over 13,000 people attend field shows at these sites during the summer. In addition, Beck's conducts plant and agronomy studies with Purdue University, and it has also developing collaborations with a number of technology firms to work on its precision agriculture projects (see below).

Advantages to Locating in Indiana

The company notes several advantages to operating from its base in Indiana:

- Focused marketing to approximately 30 percent of the U.S. corn and soybean acres.
- Close proximity to excellent roads which allows for the shipment and transportation of processed seed products.
- Proximity to land grant universities and agricultural colleges which provide an excellent opportunity to recruit talent.
- Favorable tax environment and solid agricultural focus among state government leaders.

Products/Activities Related to Other Innovation Sectors

New areas of innovation in agbiosciences and associated technologies are being leveraged by Beck's for growth in novel markets in other innovative fields.

Beck's Work in Precision Agricultural Sensing and Information Technology:

Beck's Hybrids recently introduced a new product line called FARMserver™. FARMserver™ provides a farmer the capability to access information from a web connected device at any time by using a simple and user-focused design. The FARMserver™ mobile app allows farmers to record geo-referenced data from the field and easily sync it to their secure FARMserver account.

Since the inception of precision agriculture, farmers have struggled with the compatibility of data collected from multiple sources. FARMserver™ not only makes farmers' data compatible, but it will provide easy to use tools to analyze the data. In addition, FARMserver™ provides a unique recordkeeping system focused at the field level; comprehensive aerial imagery that delivers deep insight into field variability; field-based weather monitoring; and a crop scouting app.

Case Studies: Agdia

Company Overview

Agdia is a privately-held company focused on providing the agricultural industry with diagnostic tools to assist in the management of plant diseases caused by viruses, bacteria, fungi, and other pathogens. The Company specializes in developing immunological and molecular diagnostic tests for plants. Agdia's tests utilize well-characterized technologies such as enzyme-linked immunosorbent assays (ELISA) and polymerase chain reaction (PCR). Not only does the Company help its customers detect pathogens, but it also provides testing solutions for detection of transgenic traits.

Formed in 1981, Agdia operates from Elkhart, Indiana. All of its corporate activities, including research, product development, manufacturing and sales, are performed in Indiana. Agdia employs 55 people and recently built a new, larger headquarters in Elkhart that will help support the Company's growth.

How Innovation has Driven Growth

Over the years, the company has adapted several advanced detection technologies utilized in human diagnostic testing to serve the plant industry. For example, technology previously used in point-of-care pregnancy tests has been converted to detect common pathogens found in crops. The product, ImmunoStrips, is used on-site by growers. Prior to these types of tests being available, a grower would send a sample to a third-party laboratory and wait days - or weeks - to receive the test results. Now the information is available immediately to the grower.

Agdia has also adapted DNA detection methods to on-site plant testing. In 2013, the Company launched the industry's first portable DNA tests, called AmplifyRP Acceler8, for two economically important pathogens in cotton and citrus. The product allows this detection method to move out of the laboratory and has been simplified it to enable non-scientists to administer molecular testing.

Collaborations

Agdia has collaborated with researchers at Purdue and other universities, and licensed technologies from other diagnostic and crop science companies.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- Proximity to major airports.
- Midwest location facilitates interaction with field-crop and trait product customers.
- Research University with strong agriculture and plant pathology programs.

Agricultural/Food Equipment and Production Technology

What Does This Sector Do?

Agricultural production and the downstream processing of agricultural outputs into value-added products requires the design, engineering, and production of specialized equipment. Agricultural production equipment represents a highly diverse market, with distinctive products and technologies required for different crops, livestock, and materials handling. Individual farms need specialized equipment to handle field preparation and soil maintenance, planting, application of crop protection chemicals, irrigation, and harvesting. Similarly, in livestock agriculture specialized systems are needed for livestock feed handling, livestock watering, housing, and other applications, such as milking or egg handling. Materials handling and storage is also another major component of the farm equipment sector, and the needs for specialized systems extends downstream into agricultural distribution and agricultural processing operations.

All of the value-added activities in food manufacturing, and biomass processing for industrial applications, also require specialized equipment, systems, and technologies. Within the food processing industry there are broad requirements for equipment for ingredients storage, materials handling, processing, heating/ cooking, pathogen deactivation, and packaging.

Why Is This An Opportunity for Indiana?

Currently, 17 firms with 1,341 employees are classified into this innovation sector. Example firms include: CTB, Inc.; Equipment Technologies; Trellis Growing Systems; and Ziggity Systems.

With almost 2.11 million individual farms in the USA alone[23], covering 914.6 million acres of land, the agricultural equipment marketplace is very large and highly diverse. The consistent pressures to increase farm yields and productivity lead to demand for new, high-performance production equipment—equipment which increasingly incorporates high-technology software and precision guidance and sensing capabilities. Increasing global demand trends also favor growth of this sector—as Alix Partners note:

- "Around the globe, human populations and per-capita calorie consumption are steadily increasing, leading to increased demand for food—which in turn raises crop prices and thus farm incomes. We expect net farm income to exceed US$125 billion by the end of 2013—the highest in 40 years (based on constant dollars). This is all good news for companies that make and sell agricultural equipment, because their revenues hinge tightly on farm incomes, particularly in developed markets."[24]
- Market researchers at the Freedonia Group are projecting that the global market for agricultural equipment will grow 6.9 percent annually through 2018 to reach $208 billion. Within the United States, a June 2014 report by IBISWorld[25] places the current size of agricultural equipment production in the United States at $41.6 billion and annual growth projected to run at 2.4 percent between 2014 and 2019. IBISWorld sizes the production environment as comprising 1,138 businesses in the United States.
- Food processing and packaging also represents a large global market. In their recent March 2014 report[26], BCC Research notes that:

[23] http://www.agcensus.usda.gov/Publications/2012/Preliminary_Report/Highlights.pdf. A farm is *"any place from which $1,000 of agricultural products were produced and sold, or normally would have been sold, during the Census year."*
[24] http://www.alixpartners.com/en/Publications/AllArticles/tabid/635/articleType/ArticleView/articleId/788/Plowing-Ahead-in-the-Global-Market.aspx#sthash.N4HaD9ou.dpuf.
[25] IBISWorld. June 2014. "IBISWorld Industry Report 33311, Tractors and Agricultural Machinery Manufacturing in the U.S."
[26] BCC Research. March 2014. "Global Markets for Food Processing and Food Packaging Equipment".

- "The global market for equipment used in food processing and packaging was nearly $20.3 billion in 2011 and is expected to reach $31.3 billion by 2018, rising at a five-year compound annual growth rate (CAGR) of 6.3% from 2013 to 2018."
- "Global markets for food processing equipment were nearly $8.1 billion in 2011 and reached $8.6 billion by the end of 2012, for growth of 6.7%. This market is expected to grow at the CAGR of 5.8% and reach $12 billion by 2018. The Europe, Middle East and Africa (EMEA) region is the leader in this category due to its large consumer base of processed foods, especially dairy and meat products. It is a highly mature and fragmented market comprising a large number of international and domestic manufacturers. The North American market is expected to experience strong growth at a CAGR of 6.8%, owing to its post-recession recovery, while the Asia-Pacific market is expected to grow at a CAGR of 5.8%."
- "The global market for food packaging equipment was nearly $12.2 billion in 2011 and reached $13.1 billion by the end of 2012. This market is expected to grow at a CAGR of 6.7% and reach a forecast market value of $19.3 billion by 2018. The EMEA region is the leader in this category. It is a highly mature and fragmented market comprising a large number of international and domestic manufacturers. The North American market is expected to grow at a CAGR of 6.3% while the Asia-Pacific market is expected to grow at a strong pace with a CAGR of 7.1%, owing to rising demand for packaging equipment in developing countries."

Overall, it is clear that global demographic and wealth trends are highly favorable for continued growth and development in the manufacturing of agricultural equipment and food manufacturing equipment.

Recent Innovation Performance

Research Publications **(2009-6/2014)**	80 publications. Key disciplines include agronomy, food science, and pest control.
Patents **(2009-2013)**	25 patents CTB, Inc. – 17 patents
Innovation Resources and Capital (2003-To Date)	
➢ USDA Funded Research (non-SBIR)	22 Awards; $11,867,820
➢ SBIR Awards	3 Awards; $525,253
➢ Venture Capital	0 Investments;
➢ 21st Century Fund	2 Investments totaling $148,734 to: Trellis Growing Systems (2)

Companies that are Actively Involved with this Innovation Sector

Company Name	Innovation Area Descriptions
A.T. Ferrell Company, Inc.	A.T. Ferrell is an engineering company that produces a variety of seed cleaning devices and seed mills.
AccuTemp Products, Inc.	AccuTemp Products, Inc. develops and manufactures commercial foodservice equipment, and is a leading supplier of connectionless-boilerless steamers and steam-heated griddles.
Banjo Corporation	Banjo Corporation is a manufacturer of liquid handling products that service agriculture and industrial applications.
Carmel Engineering, Inc.	Carmel Engineering, Inc. designs, engineers and manufactures custom equipment and systems for process and food manufacturing industries.
Clear Creek & Associates, Inc.	Clear Creek & Associates is a structural, agricultural and facility engineering company specializing in custom agricultural and bulk processing facilities.
CTB, Inc.	CTB, Inc. is a leading designer, manufacturer and marketer of systems and solutions for preserving grain; producing poultry, pigs and eggs; and processing poultry.
Double C Ranch Supply LLC	Double C Ranch Supply LLC is a full equine training facility specializing in everything from colt starting to performance horses, and also has designed an equine watering system.
Equipment Technologies	Equipment Technologies designs and manufactures Apache ET Sprayers, a line of self-propelled crop sprayers.
Farm Innovators, Inc.	Farm Innovators, Inc. produces a broad line of de-icers and heated products to solve the problem of frozen water for animals during the winter.
Hensley Fabricating and Equipment Co., Inc.	Hensley Fabricating and Equipment Co., Inc. produces and supplies high capacity trailers and trailer bodies for farm use, as well as commercial and industrial bucket elevator systems for moving grain.
Iotron Industries USA Inc.	Iotron produces electron beam radiation systems for varied applications including food irradiation.
Laidig Systems, Inc.	Laidig Systems designs engineers, markets, fabricates, installs, and services products for the bulk storage and reclaim industry, specializing in screw-type bottom reclaimers in silos, domes, and open piles.
Mid-West Metal Products Co., Inc.	Mid-West Metal Products Co., Inc. is a manufacturer of wire-formed, sheet metal and tubular metal fabrications with agbioscience applications such as animal and pet enclosures.
Murray Equipment, Inc.	Murray Equipment, Inc. specializes in the manufacture and distribution of difficult liquid handling equipment systems such as crop protection chemicals, liquid fertilizers, crop oils, liquid feeds and acids in the agricultural industry.
Riley Equipment, Inc.	Riley Equipment designs and manufactures processing machinery and bulk material handling equipment for grain, fertilizer, seed, feed, aggregate & mining and a wide variety of industrial markets.
Trellis Growing Systems, LLC	Trellis Growing Systems, LLC is the inventor/developer of a rotating/multi-position trellis system designed to grow blackberries and other vining berries.
Ziggity Systems, Inc.	Ziggity Systems, Inc. develops watering systems for poultry production applications that offers drinkers for broilers and drinkers for layers that can be retrofitted onto an existing watering system without replacing the entire system.

Case Studies: Equipment Technologies

Company Overview

Equipment Technologies is a prime example of agricultural innovation driving the development of new companies and the creation of new jobs. In the mid-1990s, the widespread adoption by farmers of the Monsanto *Roundup Ready*™ products as the preferred method for weed control opened a new market for self-propelled sprayers as herbicide applications could be applied post emergence. This innovation in plant science and crop protection chemistry ultimately changed innovation in the agriculture machinery market.

The major multi-national farm machinery manufacturers understood the implication of the *Roundup Ready*™ adoption, but incorrectly predicted that machinery would continue to be tailored to meet the needs of the fertilizer dealer with large, expensive, heavy machines. The founder of Equipment Technologies, a start-up company created in 1997 in Mooresville, Indiana, correctly predicted that, instead, the growth in the market would be driven by the individual farmer who would demand a lighter, simpler, less expensive machine.

To meet this predicted demand, Equipment Technologies invented a direct-drive train, high-clearance sprayer that has now been installed on more than 5,000 farms in North America, ranking Equipment Technologies within the top four sprayer manufacturers globally.

Today, Equipment Technologies is the largest independently owned manufacturer of self-propelled sprayers in North America, and operates out of a 168,000 square foot headquarters in Mooresville. The company distributes through both a direct sales force of in-house dealerships, as well as through independent dealers in North America, Australia and Ukraine.

How Innovation has Driven Growth

Equipment Technologies developed a direct drive-train, mechanical transmission technology, which was lighter, simpler, and less expensive, and based on its proprietary gear box, had the high-clearance that was required for row crops. Its primary competitors chose hydrostatic wheel motors, which are heavier, less reliable, and much more expensive. The application of what in many ways was older, off the shelf technology, created a dominant position in the world market for ET Sprayers.

Collaborations

While Equipment Technologies initially conducted all of its design work for the sprayer, its close collaborations with many of its supply chain partners has helped to keep the company on the cutting-edge. Today, the company has over 100 suppliers building the nearly 700 parts for the three sprayer models that it builds, with the vast majority of the suppliers based in Indiana. As a result, a lot of the continued innovation/assessment occurs within the suppliers who conduct significant R&D to help ensure the machine remains on the cutting edge of technology.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- Indiana's historic fabricated manufacturing experience has enabled the company to grow through the utilization of excellent automotive and other industrial suppliers.
- The state's central location provides comparative advantage in terms of distribution channels.
- Strong workforce with Hoosier values that help connect the company to its customers.
- Pro-business climate that is supportive of expansion/growth.

Case Studies: CTB, Inc.

Company Overview

As the world's population grows and emerging markets advance, the demand for feed, grain and animal protein will continue to increase. Positioned to help meet this growing demand, CTB, Inc., a Berkshire Hathaway Company located in Milford, Indiana, is a leading designer, manufacturer and marketer of systems and solutions for preserving grain; producing poultry, pigs and eggs; and processing poultry. CTB seeks to develop innovative systems that preserve the quality of harvested grain through applying the latest technology in structures, storage, handling, conditioning and drying, as well as creating systems to help produce animal protein with maximum efficiency. These innovations are applied with a commitment to animal care and air quality management.

Founded in 1952, CTB has grown through both innovation and acquisition, and markets its systems and solutions under a variety of prominent brand names, such as BROCK®, CHORE-TIME®, FANCOM®, MEYN®, PIGTEK®, ROXELL® and others. With sales totaling approximately $1 billion in 2013, CTB employs more than 2,500 individuals globally, with approximately 600 located in Indiana.

How Innovation has Driven Growth

Every agricultural business is looking to find efficiencies and improve yield. CTB focuses on finding incremental solutions through cutting edge technology to solve the common problems experienced today by agricultural producers. By holistically examining solutions from a systems perspective – from silos to conveyors to elevators to dryers – CTB focuses on finding efficiencies, maximizing productivity, and eliminating waste in grain production. CTB has also successfully driven innovation into animal feed systems by observing animal behavior and introducing animal-friendly products, which in turn leads to increase in feed efficiencies and reduction of waste throughout the system.

Collaborations

CTB has developed a number of collaborations with university research partners to help drive product improvement innovations. For example, CTB enlisted the expertise of a local university to determine the cause of metal fatigue in a key feeding system component. Once the cause was identified, CTB engineers were able to modify the material specification successfully. In addition, CTB's Instrumentation & Controls Group has worked with a number of universities to develop systems to monitor and respond to poultry flock movement in the barn, auditory detection of pig coughing, and camera detection of pig growth. CTB engineers are also involved on a number of Purdue's poultry and livestock scientific and industry advisory boards.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- The state is well positioned as a center of production agriculture, which allows the company to be directly in touch with its customers.
- Strong workforce with excellent work ethic.
- Hoosiers understand agriculture and provide a supportive culture and climate for agribusiness development.

Animal Health and Nutrition

What Does This Sector Do?

The animal health and nutrition sector focuses on providing advanced nutrition/feed products and the therapeutics and diagnostics to maintain the health and productivity of livestock and poultry, as well as the health and well-being of companion animals. The sector includes organizations engaged in all aspects of animal health and nutrition including medicines and vaccines, diagnostic and testing services, veterinary and breeding services, and specialized animal nutrition products.

Why Is This An Opportunity for Indiana?

Currently, there are nine firms identified as being involved in animal health and nutrition with an employment base of 1,159. Example firms include: Cook Animal Health; Elanco Animal Health; JBS United; Micronutrients; MLF Biotech; and Whiteshire Hamroc.

Global demand for the products of livestock agriculture is projected to continue along a growth trajectory based upon both expending human population and increasing purchasing power (which is correlated with an increasing demand for livestock products). As with crops, the vast majority of sustainably utilized land for livestock worldwide is already in production. Achieving significant growth in the industry to meet rising demands will require the production sector to increase productivity. Innovations in livestock productivity will come through three primary channels:

- **Breeding and genetic improvement of livestock** – Livestock producers in the developed world are using both traditional breeding and modern molecular genetics techniques to identify livestock with enhanced productivity traits and to increase the production of lines with the positive production traits. Widespread acceptance of artificial insemination techniques greatly facilitates the procreation of improved lines.
- **Enhanced nutrition and feed products** – Meeting the energy, protein, mineral, and vitamin needs of ruminant and non-ruminant livestock is another key technological focus in agbioscience. Advanced knowledge of livestock digestion, gut metagenomics, and other factors are promoting the development of highly accurate and customized feed and nutrition supplement regimens.
- **Veterinary medicine** – Animals contracting diseases or parasites have to use feed energy resources to fight their illness, instead of using these energy resources to grow. Productivity is lost to livestock illnesses, and a considerable volume of antibiotics and other drugs are used in livestock production to counteract disease and parasite-driven productivity losses. In addition major disease outbreaks (e.g. BSE, Foot and Mouth, Avian Influenza, etc.) can lead to the culling of entire herds/flocks and large-scale economic losses. As such, veterinary medicine is an integrated component of modern animal agriculture.

These areas of animal agriculture activity each comprise significant markets, although of the three, the nutrition and feed and the veterinary medicine markets are by far the largest.

The International Feed Industry Federation places the size of the global commercial feed production industry at $370 billion.[27] IBISWorld, in its December 2012 report on the U.S. farm animal feed industry shows industry revenues of $31.7 billion with annual growth between 2012 and 2017 projected to be 1.4

[27] http://www.ifif.org/pages/t/The+global+feed+industry

percent.[28] The IBISWorld report projects that 39.8 percent of U.S. feed production is for dairy and beef cattle feed; 37.7 percent for poultry; 21.5 percent for swine, and one percent for other livestock species.

One of the more dynamic aspects of the livestock feed market is in the area of feed supplements. Research and Markets notes that "the global animal feed additives industry, which stands at $31.4 billion in 2013, is growing at a CAGR of 4.1% to reach $ 43.2 billion by 2020."[29] Products in this arena comprise vitamins, amino acids, antibiotics, anti-oxidants, enzymes and other nutritional supplement elements added to livestock feed.

BCC Research estimates that the total global market for animal therapeutics and diagnostics was $30 billion in 2011, up from $25 billion in 2008. By 2016, this market is likely to exceed $42 billion, with a five-year compound annual growth rate (CAGR) of 7.2 percent from 2011 through 2016.[30]

Among the key market drivers involved in animal health are:

- Increased consumer interest about the conditions of how their food is produced, and requiring improved feeding plans and more proactive approaches on disease control.
- Increased FDA scrutiny on food safety.
- Growing concerns about antibiotic resistance and its transfer to humans.

While the market for animal health is generally considered to be competitive and fragmented, divisions of major pharmaceutical companies do dominate across all segments of the market.

In contrast to human blockbuster-oriented pharmaceuticals, animal health and nutrition is dominated by large numbers of products with relatively smaller revenues. Although there are hundreds of products involved in this market, only about 30 products have sales exceeding $100 million per year.[31]

Key segments of the animal health and nutrition market include:

- Pharmaceuticals, which is nearly half the market for animal therapeutics and diagnostics, led by anti-infectives, parasite control, and other specialized drugs.
- Feed additives, which is the second largest market segment for animal health, involving medicinal additives, nutritional additives, vitamins, and amino acids.
- Biologics, which is the fastest growing market segment, comprising primarily vaccines and blood products.
- Diagnostics, which is a small segment of the market, involving rapid testing products, clinical laboratory equipment, and imaging equipment.

Overall, it is clear that global demographic and wealth trends are highly favorable for continued growth and development in the animal health and nutrition sector. Indiana is favorably positioned to take advantage of these growth opportunities not only as a result of its significant livestock production capacity, including the diversity of its species, but also due to the innovative companies located in the state that are well positioned in the global market and supported by a number of strong research assets.

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[28] IBISWorld. December 2012. "IBISWorld Industry Report OD4613: Farm Animal Feed Production in the U.S."
[29] Research and Markets. "Global Animal Feed Additives/Supplements Market 2014-2020: Vitamins, Amino Acids, Acidifiers, Antibiotics, Anti-Oxidants and Enzymes."
[30] ibid
[31] See BCC Research, Global Markets for Animal Therapeutics and Diagnostics, Product Brochure, HLC034C, 2012 at www.bccresearch.com.

Recent Innovation Performance

Research Publications **(2009-6/2014)**	662 publications. Key disciplines include veterinary medicine, animal science, dairy science, food science, and agricultural chemistry. Elanco – 69 publications in this sector (84 total)
Patents **(2009-2013)**	11 patents Elanco (Lilly) – 10 patents

Innovation Resources and Capital (2003-To Date)	
➢ USDA Funded Research (non-SBIR)	20 Awards; $5,211,576
➢ SBIR Awards	1 Award; $430,000
➢ Venture Capital	0 Investments
➢ 21st Century Fund	0 Investments

Companies that are Actively Involved with this Innovation Sector

Company Name	Innovation Area Descriptions
Belstra Milling Co., Inc.	Belstra Milling Co., Inc. is a manufacturer of feed for a variety of animals and supplier of agricultural products.
Cook Animal Health	Cook Animal Health is a veterinary pharmaceuticals and health products company formed by Cook Biotech that is seeking to commercialize innovative technologies discovered by others.
Elanco Animal Health	Elanco, a division of Eli Lilly & Co., is a global animal health, protein and food-production safety company, with more than 35 agricultural and animal health products approved in more than 80 countries worldwide.
JBS United	JBS United is a global leader in animal nutrition and health providing research-based products worldwide to owners and producers of various animal species.
Lowe's Pellets & Grain, Inc.	Lowe's Pellets & Grain, Inc. manufactures feed for swine, cows, horses and goats, as well as feed specifically for show animals.
Micronutrients	Micronutrients is a global mineral feed ingredient producer that develops, manufactures and markets high quality trace mineral products.
MLF Biotech, Inc.	MLF Biotech, Inc., part of Maple Leaf Farms, specializes in animal health and nutrition by promoting a healthy digestive tract in the animal through the use of probiotics and by protecting it from ingested toxins through toxicity testing services.
Sauder Feeds	Sauder Feeds manufactures a wide variety of animal feeds and custom formulated feeds, as well as animal nutrition, health and equipment products.
Whiteshire Hamroc	Whiteshire Hamroc is a swine breeding and genetics company that also produces an innovative building and ventilation system for swine breeding.

Case Studies: Elanco

Company Overview

Elanco, a division of Eli Lilly and Company, is a global, innovation-driven company that develops and markets products and services to improve animal health and protein production in more than 75 countries. From its headquarters in Greenfield, Indiana, Elanco focuses on developing treatments for some of the most harmful diseases in animal health, including ileitis in swine, coccidiosis in poultry, and Bovine Respiratory Disease in cattle, as well as providing products that target common threats such as fleas and heartworm disease, and growing medical conditions like separation anxiety.

Elanco has helped shape the animal health industry for more than half a century. Since introducing its first antibiotic for veterinary use in 1953, the company has delivered more than 35 agricultural and animal health products to the marketplace. Today, with approximately $2 billion in annual sales, Elanco employs more than 3,000 people worldwide with approximately 750 individuals located in Indiana. In 2013, Elanco ranked No. 4 among global animal health companies, and will become No. 2 once its announced acquisition of Novartis Animal Health closes in early 2015.

How Innovation has Driven Growth

For more than half a century, Elanco has built a legacy of innovation in animal health. By conducting significant internal R&D throughout the company's history, Elanco was able to launch successful products into the market place, averaging approximately one new product every ten years. In 2007, recognizing that faster growth would come through diversification, Elanco focused on increasing its innovation cycle. The primary means to increasing the number of innovations was through strategic acquisitions—Ivy Animal Health in 2007, Posilac®(rbST), a dairy cow supplement that improves milk productivity, from Monsanto in 2008, European rights to a portfolio of Pfizer Animal Health products in 2010, ChemGen, a privately-held enzyme company, in 2012, and Lohmann SE, which helps to establish Elanco as a global poultry leader and expand its growing vaccine presence. These strategic acquisitions have enabled Elanco to double its business volume in just over five years.

The legacy of rapid innovation continues today through data analysis, quality manufacturing systems, new product development (such as vaccines), and forward-thinking partnerships with biotechnology firms worldwide. For instance, Elanco recently announced an agreement to acquire Novartis Animal Health, which will strengthen and diversify the company's own animal health business. Upon completion of the acquisition, Elanco will be the second-largest animal health company in terms of global revenue, will solidify its number two ranking in the U.S., and improve its position in Europe and the rest of the world.

Collaborations

Elanco has numerous collaborative research relationships around the world. The company thinks globally about partnerships and are agnostic with regards to where the capabilities are located. The company does note, however, that the Midwest is ripe with research competencies and it views Purdue as a world-class player in the agbioscience domain. Elanco employs many of its graduates and conducts research projects each year with the university. That being said, based on its business model, Elanco's preference is to wait later in the development life cycle in terms of adopting new technologies so that proof-of-concept can be established. Typically, that means technology will first be developed further by a biotech, pharma, or other company before Elanco will bring it in-house for further development into a marketable product.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- Supportive culture and climate for agribusiness development;
- Logistics and distribution advantages due to proximity to major markets;
- Quality and sophistication of available workforce; and
- Strong network of world renowned research universities that emphasize the importance of industrial partnerships.

Case Studies: JBS United

Company Overview

Founded in 1956, JBS United is a global leader in animal nutrition and health providing research-based products worldwide to owners and producers of various animal species. JBS United encompasses seven premix/base-mix feed mills, seven grain facilities (two of which are grain terminals), and four research farms across the country. As the company continues to grow, its areas of expertise have grown to include research-based animal nutrition and health products, nutritional biotechnology applications (including feed enzymes and direct-fed microbials/ probiotics), swine production, grain merchandising, and environmental consulting services. With headquarters in Sheridan, Indiana, JBS United is a privately-held company with annual sales revenue of nearly $600 million employing over 360 people around the world, with over 180 employees located in Indiana.

How Innovation has Driven Growth

In 1970, JBS United built the company's first research farm with the idea that in order to properly advise its customers it had to test how its products and ideas performed in a production environment that closely resembled its customers' systems. Today, JBS United has more swine research farms than any nutrition company in the United States, including specific farrow-to-finish, breed to wean, and wean to finish research farms that contain multiple discovery centers and nutrient management facilities. The research, innovation, and product development team conducts over 100 trials a year, and works in conjunction with several universities, commercial pig production systems, and scientists in the U.S. and abroad. Through those relationships and business investments, innovative applications for optimizing livestock digestive health and swine reproductive performance have been developed and commercialized for global distribution.

One area of constant innovation is its nursery nutrition products. Continual research is done to evaluate and optimize nutritional concepts and management strategies, and identify biologically-effective and economically-viable nursery feed ingredients. Knowledge gained from these activities is utilized to routinely revise nursery feeds and then test those revisions in commercial scale nursery and wean to finish production settings. This research is focused on product improvements that will translate into increased profitability for their customers.

Collaborations

JBS United has developed a collaborative relationship with Purdue University's swine and poultry specialists, and focuses its research efforts on animal nutrition and health issues, particularly related to feed enzymes and their effect on efficient diet utilization.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- Supportive culture and climate for agribusiness development;
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- Quality and sophistication of available workforce; and
- Strong network of world renowned research universities that emphasize the importance of industrial partnerships.

Case Studies: Whiteshire Hamroc

Company Overview

Whiteshire Hamroc is a foundation swine genetics company with the most elite Yorkshire, Landrace, and Duroc genetics in the world. According to the registrations at the National Swine Registry (NSR), Whiteshire Hamroc is the largest recorder of Yorkshire and Duroc, and the second largest recorder of Landrace swine in the nation. The company's large herd size allows it to provide swine genetics to producers of various sizes both domestically and internationally. With sales totaling $12 million in 2013, Whiteshire Hamroc employs 45 individuals.

Founded in 1977 in Albion, Indiana, Whiteshire Hamroc prides its growth and success on its ability to innovate and initiate change. For example, while for 30 years Whiteshire Hamroc has been combining innovative genetic improvement techniques with stockmanship evaluation skills to produce elite swine breeding stock, it also recognized from its own observations and the experiences of its customers that various environments can cause stresses on pigs and impact their production. After 15 years of research and testing, Whiteshire Hamroc developed an innovative and patented building and ventilation system. The company's nimbleness continues to open up new markets for the company to pursue.

Whiteshire has adopted precision agriculture in its cropping enterprise as a way to maximize the effectiveness of inputs, agronomically apply manure, protect the environment, and provide data for current and future cropping decisions. Investment and education about new agronomic technologies continue to pay big dividends.

How Innovation has Driven Growth

Whiteshire Hamroc has focused its efforts on improving its client's profitability by influencing through innovation herd health, genetics, and environment. With regards to herd health, the company has a stringent health control and bio-security focus, operating primary and secondary specific pathogen free (SPF) herds. With regards to genetics, Whiteshire Hamroc uses a combination of proven technologies (Herdsman, STAGES, and "Real-time" scanning) with phenotypic selection to continually improve its genetics and build more productive, profitable seedstock.

Whiteshire's interest in the health control of its pig production has resulted in its engagement with the human health sector to investigate and apply animal products and tissues that can enhance human health and vitality. These products have already improved the lives of many recipients and new opportunities are on the horizon.

Finally, through its patented building and ventilation system, AirWorks®, livestock are able to express their genetic potential. AirWorks® has consistently demonstrated a 50 percent decrease in swine death loss, a marked improvement in feed efficiency, substantially increased weaned litter weights, fostered overall healthier pigs, and noticeably decreased energy needs.

Collaborations

Whiteshire Hamroc has developed a collaborative relationship with Purdue University, particularly with its geneticists. Purdue geneticists have provided technical assistance, and the company confers with various faculty members on a monthly basis. The company plans to develop a research farm in late 2015, at which time it expects to work more closely with Purdue in live animal R&D and demonstrations.

Advantages to Locating in Indiana

The company notes that the greatest advantage in being located in Indiana is the fact that the state government is supportive of agriculture and provides a positive culture and climate for agribusiness development.

Case Studies: Micronutrients

Company Overview

In 1992, the Heritage Group of Indianapolis, Indiana launched a research project with the hopes of reclaiming copper from etchants used to produce printed circuit boards for computers and other electronics. The project resulted in the development of a high-rate crystallization process to make dicopper chloride trihydroxide. Because of its neutrality, insolubility in water, and high copper content, this product was studied as a potential source of nutritional copper in animal diets. After numerous feed stability and animal feeding trials, a favorable opinion letter from the FDA on the safety of using basic copper chloride as a nutrient in animal feed was received, and patents were obtained on the application of this compound as a source of nutritional copper, one of the trace metals essential for life. The product was test marketed in the animal feed industry as Micronutrients TBCC® (TBCC), resulting in the birth of both an innovative new feed ingredient and an innovative new company – Micronutrients, a division of Heritage Technologies, LLC. Since its birth, the company has continued to develop, produce, and market other successful mineral feed ingredients that outperform traditional products.

Today, Micronutrients is a global mineral feed ingredient producer. The company's products have been proven by independent research (more than 100 research trials to date) to improve animal productivity and health while minimizing handling costs and environmental impact. With its headquarters, domestic production base, and R&D operations in Indianapolis, Indiana, Micronutrients has grown to a company with annual sales revenue of nearly $100 million employing approximately 100 people in the state. Furthermore, Micronutrients, which has recently completed a significant expansion that enabled the company to triple its production capacity, has expanded its original product line to offer a wide range of trace minerals, including copper, zinc and manganese-based products.

How Innovation has Driven Growth

Seeking ways to innovate is an integral part of the company's culture. Micronutrients itself started as a research project that turned into a business. Its hydroxyl trace minerals employ specific "smart" bonds that are strong enough to remain intact in animal feed mixtures and in the upper gastrointestinal tract while remaining ideal for optimal absorption by the animal. Because of their smart bonds, Micronutrients' products provide essential minerals that are more consistently and completely available for use by the animal. Efficient mineral utilization results in a wide array of benefits, including increased growth rates, improved feed efficiency, increased carcass yield and quality, improved fertility, and overall well-being—while reducing environmental impact. Through continual evolution of its original concept for a manufacturing process, the company has developed economic ways to make any essential mineral in its novel hydroxy form—making stable combinations of minerals from an array of raw materials.

Collaborations

While Micronutrients has undertaken significant internal R&D efforts to develop and patent its technologies, it has also worked closely with companies in the region, such as JBS United. In addition, the company works with universities around the world, including Purdue University, University of Illinois, North Carolina State University, California Polytechnic State University, to name just a few.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- Productive/talented workforce with strong work ethic;
- A pro-business climate in which the government has supported the company's expansion activities;
- Geographical proximity to the heart of animal production activities; and
- Indianapolis' success in bringing scientific conferences/symposiums to the region fostering access to worldwide knowledge and expertise.

Precision Agriculture Sensing and Information Technology

What Does This Sector Do?

Precision agriculture sensing and information technologies provide the tools and information farmers need to optimize and customize the timing, amount, and placement of seed, fertilizer, pesticides, irrigation, and other inputs to produce the maximum yield at the lowest cost. It is an emerging set of technologies that involve the use of advanced information technologies to gather, track, and analyze agricultural data, usually in conjunction with other systems such as harvesting or field-input machinery. It includes organizations engaged in information- or computer-oriented agricultural technologies including agricultural software, sensors and monitoring systems, modeling technologies, and unmanned aerial surveillance (UAS) technologies. Specific activities of precision agricultural companies include geographical information systems development, yield monitor development, variable rate controls, air and ground steering systems, and technical support services. *The Economist* views precision agriculture as "the biggest change to agriculture in rich countries since genetically modified crops."[32]

Precision agriculture is being driven by Big Data. Big Data involves an ongoing major paradigm shift in the processing and use of data. Rather than looking at data collected to assess what occurred in the past to make decisions—which is today's standard approach to using more high powered analytics to analyze massive data sets stored in data warehouses—this new paradigm will be using real-time continuous processes for sensing, gathering, protecting, analyzing, and interpreting data that allows one to improve an outcome during an event based on real-time information from sensors, radio frequency identification, and other devices.[33] AgInformatics is the study and practice of creating, storing, finding, manipulating, and sharing food and agricultural information and data along the entire value-chain.

Why Is This An Opportunity for Indiana?

Currently, there are ten firms identified as being involved in precision agriculture sensing and information technology with an employment base of 63. Example firms include: 360 Yield Center; FarmWorks Information Management; Precision Hawk; and Spensa Technologies.

According to IBISWorld, the leading states with strong precision agriculture sensing and information technology sectors are found in the Southwest, Southeast, and West, with each of these regions having close to 20 percent or more of the precision agriculture establishments in the nation. The Midwest and Plains states, meanwhile, have less than ten percent of precision agriculture establishments. The number of start-up companies in Indiana in this sector is modest. In Indiana, much of the precision agriculture R&D and implementation is occurring at larger companies such as Beck's Hybrids (FARMserver™) and Dow AgroSciences (John Deere collaboration).

Other key success factors identified by IBISWorld as particularly important for the precision agriculture sensing and information technology sector include having access to:

- A highly trained technical workforce with a diverse set of software-hardware skills able to integrate the multiple technologies required for precision agricultural solutions, including remote monitoring, automated controls, and data analytics.
- New technological advancements found in a robust research and development environment in order to be able to identify and quickly adopt these new technologies into precision agriculture products.

[32] Schumpeter, "Digital Disruption on the Farm," The Economist, May 24, 2014.
[33] See Davenport, Barth and Bean, "How "Big Data" is Different," MIT Sloan Management Review, July 30, 2012.

There are a range of views on the future growth of precision agriculture.[34] The current market for precision agriculture in the United States is estimated in excess of $1.5 billion. Some market researchers view it as a very fast moving market with expected compound annual growth of over 13 percent from 2013 to 2018, while others view the market growing at a more modest pace of under seven percent. Even under the less optimistic forecasts, the market for precision agriculture in the United States is expected to reach close to $2 billion by 2018, employing over 5,000 workers.

The key uncertainties for future growth are how much precision agriculture will penetrate the market beyond the largest agribusinesses, and whether smaller farmers will be slow to adopt the technologies involved (and possibly reluctant to have precision agriculture companies have access to data about their farms). There are also uncertainties regarding whether smaller farmers will be able to afford the investment in precision agriculture if there are lower prices for crops or farmers are unable to access financing. It is also expected that the pace of new product introductions will be critical and will depend upon new regulations for the commercial use of unmanned aerial systems as well as continued technological advancements in global positioning systems, remote sensing, automated piloting, and modeling and simulation technologies.

Recent Innovation Performance

Research Publications (2009-6/2014)	20 publications. Key disciplines include agriculture/agronomy and instrumentation.
Patents (2009-2013)	0 patents
Innovation Resources and Capital (2003-To Date)	
➢ USDA Funded Research (non-SBIR)	10 Awards; $3,529,000
➢ SBIR Awards	0 Awards
➢ Venture Capital	1 Investment for $300,000 to: Spensa Technologies by Elevate Ventures
➢ 21st Century Fund	1 Investment for $1,000,000 to: AquaSpy
➢ Innovate Indiana Fund	2 Investments in Precision Hawk.

Since the precision agriculture sensing and information technology sector in many cases is being driven by smaller, emerging companies, it is discouraging to see such little activity in the area of patents, SBIR awards, and venture capital in Indiana. However, the indigenous risk capital investments made to date in two emerging companies, AquaSpy and Precision Hawk, indicate there is an emerging understanding of

[34] Market intelligence is drawn from several reports including: IBISWorld, Precision Agriculture Systems and Services in the U.S., May 2014; Focus Investment Banking, Precision Agriculture: Special Market Report, Winter 2014; and news releases from MarketsandMarkets, Precision Farming Market: Global Forecast and Analysis 2013-2018.

the potential market opportunity. It will be critical to support the growth of these entrepreneurial companies as this Innovation Sector's growth accelerates.

Companies that are Actively Involved with this Innovation Sector

Company Name	Innovation Area Descriptions
360 Yield Center	360 Yield Center is a crop consulting company that provides seed, nitrogen and fertility solutions to farmers in western Ohio, eastern Illinois and north central Indiana.
AgSync	AgSync produces logistical tools that allows farmers to communicate between personnel and farm machines, gather data on their crops, and handle invoicing/financial procedures.
AquaSpy	AquaSpy produces an automated water and nutrient sensor system that provides feedback/recommendations for farmers.
FarmWorks Information Management	FarmWorks Information Management produces software solutions for farm management including field mapping, farm accounting, drainage designing and livestock and personnel management.
ISOBlue	ISOBlue is an open source project, supported by Purdue University, working to get agricultural data to the cloud by advancing the ISOBUS bluetooth technology that allows tractors and other farm equipment to transmit data from the field to a farmer's smart phone.
LoadOut Technologies (owned by LexTech)	LoadOut develops technology designed for the agricultural and industrial sectors that allows employees to monitor and control complex industrial processes from smartphones.
MyFarms	MyFarms brings data together from farm suppliers, buyers and producers to leverage big data in the agriculture sector.
Precision Drone LLC	Precision Drone manufactures crop surveillance drones for the agricultural industry that farmers can use to assess their crops.
PrecisionHawk	PrecisionHawk produces deployable UAVs for terrain sensing with numerous applications including agricultural monitoring.
Spensa Technologies Inc.	Spensa Technologies develops products for the agriculture industry that reduce reliance on manual labor, foster eco-friendly farming, and increase crop production efficiency.

Case Studies: Spensa Technologies

Company Overview

Spensa Technologies (Spensa) is a privately-held company developing products for the agriculture industry that reduce reliance on manual labor, foster eco-friendly farming and increase crop production efficiency. The company was founded in 2009 by Dr. Johnny Park, an assistant research professor at Purdue University School of Electrical and Computer Engineering.

Spensa has developed software and hardware products for agricultural producers, advisors and consultants in the fruit industry. Spensa's first product, Z-Trap, is a fully-automated, insect trapping system. This hardware captures insects in the field and sends insect data wirelessly to Spensa's mobile software application - MyTraps. This data - and its visualization – provide a pest management tool for fruit growers (primarily orchards), state extension educators, crop consultants, large consulting organizations and pesticide manufacturers.

Spensa is located at the Purdue Research Park in West Lafayette. All of its corporate activities, including research, product development, manufacturing and sales, are performed in Indiana. Spensa currently has a staff of 12. Since its inception, the company has raised over $3 million from grants, angel and institutional investors. The Company estimates that sales of its two products will increase by 400 percent in 2014.

How Innovation has Driven Growth

With the combination of a hardware product and related mobile software application, Spensa has developed an innovative solution to several problems facing orchards. Utilizing robotics, machine learning and wireless sensor networks, Spensa provides orchards with information that they can utilize to more effectively and efficiently detect specific pests and apply insecticide only where it is needed. Spensa's products replace manual, repetitive processes and provide real-time information instead of weekly or monthly data. Moving forward, Spensa's product innovation will rest upon its collective expertise in hardware (sensors, wireless networks, robotics, and batteries) and software. In a time when farmers need to produce more food and reduce their environmental impact at the same time, Spensa's tools help their customers implement "precision agriculture".

Collaborations

Spensa has formal research and development collaborations with companies in the plant science and crop protection industries. These efforts cover domestic and international markets.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- Indiana's sizeable agriculture industry.
- Research universities creating a pool of potential employees.
- Support for start-up companies from both Purdue University and Indiana state government.

Aquaculture and Aquatic Systems

What Does This Sector Do?

This sector includes organizations engaged in aquaculture-related equipment, aquaculture production, and input-to aquaculture production. It also includes other aquatic-based production technologies, such as algae-based technologies.

Why Is This An Opportunity for Indiana?

Currently, eight firms with 62 employees are classified into this innovation sector. Example firms include: Algaeon; Aqua Manna; and Bell Aquaculture.

Driven by global population and wealth increases, in combination with recognition of the health benefits of fish and other aquatic species in the human diet, demand for aquaculture products is projected by the Food and Agriculture Organization of the United Nations (FAO) to continue to grow significantly.[35] The FAO notes that "aquaculture continues to be the fastest growing animal food-producing sector" and that, given the fact that capture fisheries production is at capacity, aquaculture is the only means to significantly raise aquatic species production for human consumption.

While demand for aquaculture output is substantial and likely to grow significantly, there remain many challenges for the industry that require R&D-based solutions. Among these are:

- Developing feed products that do not require harvesting of wild forage fish;
- Developing feed products that sustain the Omega fatty acid and other functional nutrient characteristics in an aquaculture production environment;
- Increasing productivity of aquaculture;
- Introducing new species or improved species for successful confined environment production;
- Reducing aquaculture impacts on water resources;
- Reducing production losses to diseases and improving the health management of aquatic species;
- Assurance of food safety and quality of products; and
- Improved production environments, harvesting technologies and distribution systems.

A recent April 2014 report by IBISWorld notes that fish and seafood aquaculture is a $1.4 billion industry in the United States, and is projected to grow between 2014 and 2019 at an annual growth rate of 1.4 percent. A total of 5,344 U.S. businesses are engaged in the sector.

[35] http://www.fao.org/fishery/topic/13540/en

Recent Innovation Performance

Research Publications (2009-6/2014)	7 publications. Key discipline is aquatic sciences.
Patents (2009-2013)	2 patents
Innovation Resources and Capital (2003-To Date)	
➢ USDA Funded Research (non-SBIR)	0 Awards
➢ SBIR Awards	4 Awards; $355,000
➢ Venture Capital	4 Investments totaling $1,030,000 to: Algaeon
➢ 21st Century Fund	4 Investments totaling $2,073,885 to: Phycobiologics (4)

Companies that are Actively Involved with this Innovation Sector

Company Name	Innovation Area Descriptions
Algaeon Inc.	Algaeon Inc. produces high-value products derived from algae for the human nutraceutical and animal/fish feed markets.
AquaCulture Enterprises, Inc.	AquaCulture Enterprises, Inc .provides comprehensive aquaculture consulting services.
AquaManna, LLC	AquaManna, LLC produces seafood that is bred indoors using proprietary aquaculture equipment.
Bell Aquaculture	Bell Aquaculture is an aquaculture facility that produces fish and offers aquaculture consulting services, aquafeed and fertilizers.
Bradley Innovation Group, LLC	Bradley Innovation Group, LLC is a holding company for Aqua Manna, LLC and Bradley Environmental Enhancement. AquaManna is a producer of aquaculture equipment. Bradley Environmental Enhancement is developing technology for the wastewater treatment industry, including innovations in aeration, mixing, solids and nitrogen control.
Northern Indiana Aquaproducts, LLC	Northern Indiana Aquaproducts, LLC is an aquaculture facility that produces both fish and hydroponic produce.
PhycoBiologics, Inc. (aka Phycotransgenics)	PhycoBiologics, Inc., a research and development company, produces and delivers biologically active proteins to humans and animals using microalgae.
RDM Aquaculture, LLC	RDM Aquaculture, LLC is an aquaculture facility that produces saltwater shrimp.

Case Studies: Bell Aquaculture

Company Overview

Bell Aquaculture was founded in 2005 to create a solution to the declining supply of Yellow Perch in the Great Lakes due to environmental factors. The vision for Bell was to build a vertically integrated aquaculture farm. Today, Bell employs industry experts in operations, hatchery, husbandry, grow out, nutrition and biological monitoring. Bell's state-of-the-art, land-based recirculating aquaculture system (RAS) facility is on the cutting edge of technology in the aquaculture industry. Bell's fish have been designated Best Choice by the Monterey Bay Aquarium's Seafood Watch® Program. Today, Bell Farms™ offers Trout, Salmon, Perch, aqua feed and fertilizers that are derived from or contribute to the life cycle of humans and fish—part of their broader philosophy to use all that is available to us to benefit humanity and our planet.

How Innovation has Driven Growth

Bell's constant focus on research and critical aquaculture systems has been a fundamental component of its business planning since the company's founding. One of its most recent innovations was the opening of the Bell Farms Aqua Feed mill in July 2014, which represents the last major step toward completion of a vertically integrated aquaculture farm. This vertical integration includes a 1000 metric ton fish farm, an in-house processing facility, and production of value added products generated from capture and cultivation of by-products.

The feeds from the mill will be tailored to the nutritional, biological, and physiological needs of specific species at key points in the life cycle of the fish. The mill will be the first of its kind to produce feed locally to service the aquaculture industry on a mass scale. Bell Farms is expected to produce approximately 2 million pounds of feed per month sourcing over half of the ingredients locally.

Collaborations

Bell depends upon collaboration and partnerships for its success. They partner with companies and organizations to share knowledge and work together to advance the aquaculture industry. Recently, Bell began to offer consulting services to other companies and organizations entering or advancing aquaculture technology and education and now supply aquaculture products and services as well.

Bell also partners with other regional aquaculture farms to provide Yellow Perch and other species to consumers. In September 2014, Bell announced a partnership with Will Allen Farms LLC (Wisconsin) and the University of Wisconsin Milwaukee School of Freshwater Sciences to grow Yellow Perch using sustainable, ecologically sound methods.

Advantages to Locating in Indiana

The company notes that there are numerous business advantages to its location in Indiana:

- Midwestern proximity to Great Lakes aquaculture research and production.
- Proximity to a large regional customer/consumer base.
- Strong support from Indiana partners, including the State of Indiana, Purdue University and the Indiana Soybean Alliance.
- Availability of commodity production and infrastructure needs for new integrated feed mill.

Chapter 5. Conclusions and Recommendations

Agriculture and its associated value-chain represents an important economic engine for Indiana. Employing over 133,765 personnel in 2012 (including 64,916 in primary production and 68,849 in value-chain industries), the agbioscience value-chain is a major employment sector in the state—a sector that grew nearly five percent in Indiana while declining 0.5 percent across the nation over the last decade.

As is the case with most modern sectors of the U.S. economy, innovation plays a very important role in agbiosciences with companies leveraging R&D to develop new and more efficient processes, equipment, and technologies to develop enhanced, value-added products to meet established and emerging market demands.

Battelle's research, reported herein, was principally designed to provide a baseline profile of the innovative agbioscience sector in Indiana. Using primarily quantitative techniques, the work serves to highlight:

- Key agbioscience R&D strengths in Indiana found across academic and other institutional and corporate R&D performers (as measured by publications and patent activity).
- Companies engaged in agbioscience innovation activities in Indiana.
- Observable clusters of corporate and academic agbioscience innovation comprising a significant base of engaged companies and evidence of robust R&D activity.

Indiana's Agbioscience Innovation Sectors with Greatest Opportunity

Considering the findings of all aspects of the Battelle research, it can be concluded that there are four main innovation sectors of opportunity for Indiana that leverage an existing industry base, R&D activity, and connect to significant future market opportunity. These four innovation sectors of opportunity include:

- Plant Science and Crop Protection
  - 19 innovative companies identified
  - 3,116 persons employed in Indiana
  - Very high patent generation (668 patents from 2009–2013)
  - Very high level of publishing activity (804 publications from 2009–June 2014)
- Value-Added Human Food and Nutrition Products
  - 30 innovative companies identified
  - 13,671 persons employed in Indiana
  - Moderate patent generation (35 patents from 2009–2013)
  - High level of publishing activity (396 publications from 2009–June 2014)
- Animal Health (Veterinary) and Nutrition Products
  - Nine innovative companies identified
  - 1,159 persons employed in Indiana
  - Moderate patent generation (11 patents from 2009–2013)
  - Very high level of publishing activity (662 publications from 2009–June 2014)

- Agricultural Production Equipment, Processing Equipment and Precision Agricultural Systems. **Note:** This is a combination of the Agricultural/Food Equipment and Production Technology Innovation Sector and the Precision Agriculture Sensing and Information Technology Innovation Sector. Due to the ever increasing role of Big Data and its impact on production and machinery technology, it would benefit Indiana to more tightly link these two innovation sectors, which together represent:
  - 27 innovative companies identified
  - 1,404 persons employed in Indiana
  - Moderate patent generation (25 patents from 2009–2013)
  - Moderate level of publishing activity (100 publications from 2009–June 2014)

Each of these four innovation sectors has significant potential for future growth and economic development in Indiana because they address large-scale, global markets with significant projected growth rates as demonstrated in Table 11.

Table 11. Indiana Agbioscience Innovation Clusters and Connectivity to Large-Scale Growth Markets

Cluster	Market Projections
Plant Science and Crop Protection	• The global seed market is projected to be valued at $85.2 billion by 2018 and is growing with a CAGR of 12.1% from 2013 to 2018.[36] • The global market for agricultural biotech (including transgenic seeds) is expected to reach $24.8 billion by 2017, up from $13.7 billion in 2011 for a CAGR of 11.4 percent. The U.S. market is expected to account for approximately 75 percent of the global market.[37] • The global seed treatment market reached $3.1 billion in 2012 and is expected to grow to nearly $4.8 billion by 2018, a compound annual growth rate (CAGR) of 8.3% for the period of 2013 to 2018.[38] The North American seed treatment market is expected to reach $1.5 billion in 2018.
Value-Added Human Food and Nutrition Products	• Sizing the total processed foods industry globally is considered problematic by market researchers. An estimate, by Euromonitor International, places the packaged food industry to be approximately $1.6 trillion globally.[39] • The probiotics ingredients, supplements and foods market represents a $27.1 billion market in 2013, projected to rise to $36.7 billion in 2018 (a CAGR of 6.2%).[40]
Animal Health (Veterinary) and Nutrition Products	• The animal nutrition sector is projected by BCC to be $106 billion globally in 2013, growing to $117.8 billion by 2018 (a 2013-2018 CAGR of 6.4%). This includes both livestock and companion animal feeds. • Compound feed (blended finished feed products) comprised $85.6 billion of the global market in 2013 and is projected to grow to $117.8 billion by 2018 (CAGR of 6.6%)

[36] MarketsandMarkets 2013, *Seeds Market By Type (Oilseed, Grain, Fruit & Vegetable, Turf, Forage, & Other Seeds), Seed Trait (Herbicide Tolerant, Insecticide Resistant, & Other Stacked Traits) & Geography - Global Trends & Forecast To 2018.*
[37] BCC Research, *Agricultural Biotechnology: Emerging Technologies and Global Markets*, 2012.
[38] BCC Research, *Seed Treatment: Technologies and Global Markets*, 2013.
[39] http://www.forbes.com/2007/11/11/growth-agriculture-business-forbeslife-food07-cx_sm_1113bigfood.html.
[40] BCC Research. *The Probiotics Market: Ingredients, Supplements, Foods. 2014.*

Cluster	Market Projections
	• The Feed Additives sector represented a $20.4 billion market in 2013, projected to grow to $26.6 billion in 2018 (5.4% CAGR)
Agricultural Production Equipment, Processing Equipment and Precision Agricultural Systems	• The global market for food processing and packaging equipment totaled $23 billion in 2013 and is projected to rise to $31.3 billion by 2018 (a CAGR of 6.3%).[41] • Market researchers at the Freedonia Group are projecting that the global market for agricultural equipment will grow 6.9 percent annually through 2018 to reach $208 billion. • IBISWorld[42] places the current size of agricultural equipment production in the United States at $41.6 billion and annual growth projected to run at 2.4 percent between 2014 and 2019.

Driven by global population and wealth increases, the demand for agricultural inputs and outputs is well assured, and states such as Indiana that sustain and grow an innovative industry base in the agbiosciences will be well positioned for economic growth. This growth will come through the development and production of technologies used in agriculture, in agricultural production itself, and in the downstream processing of agricultural commodities into value-added products.

Advancing Innovative Agbiosciences in Indiana

It is clear that Indiana is operating from a position of strength in agbiosciences, both in terms of its innovative corporate sector and the R&D base in academe, primarily concentrated within Purdue University. This position, however, can be strengthened further through collaborative actions and by policies and strategies purposefully designed to enhance the Indiana operating environment and innovation ecosystem in agbioscience.

Battelle has previously performed assessments of the broader life sciences innovation ecosystem in Indiana for BioCrossroads, and a number of the conclusions from this previous work have direct bearing on strategic actions that would enhance the state's agbioscience-based development. In Battelle's report, entitled *Advancing Indiana's Life Sciences Competitiveness and Strategic Collaborations*, a series of staged actions were recommended to propel Indiana towards realizing its full potential from life science based economic development. In particular, these actions emphasized enhancing the connectivity of industry and university stakeholders in collaborative research and innovation commercialization, and are illustrated in Figure 10.

Specific to agbiosciences, it should be noted that Purdue University and certain companies in Indiana, such as Dow AgroSciences, enjoy a comparatively close working relationship, with a strong base of knowledge regarding respective capabilities. However, this is not a universal situation spanning all Indiana innovative agbioscience companies. There exists opportunities to incentivize and build a higher level of collaborative R&D engagement between Indiana actors.

[41] BCC Research, *Global Markets for Food Processing and Food Packaging Equipment*, 2013.
[42] IBISWorld. June 2014. "IBISWorld Industry Report 33311, Tractors and Agricultural Machinery Manufacturing in the U.S."

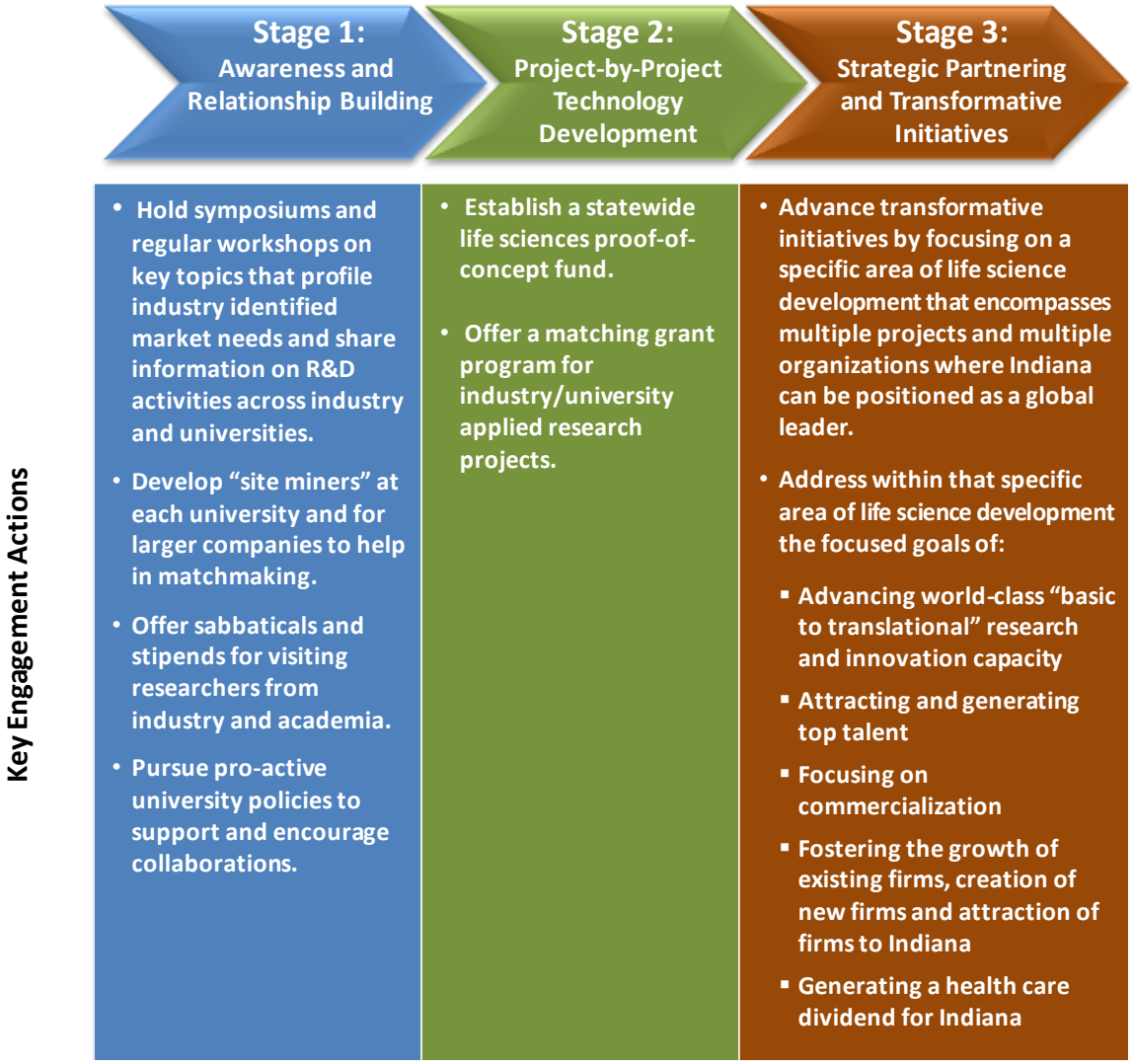

Figure 10: Three Stages of Engagement Actions between Industries and Universities to Advance Life Sciences Development

Each of the engagement actions illustrated on Figure 10 are relevant to advancing Indiana's innovative agbioscience sector—and thus their pursuit by IFAII is encouraged.

It should be noted that Battelle's evaluation of innovative agbiosciences in Indiana was performed to generate baseline knowledge of the industry and associated R&D activity in Indiana. The work did not involve in-depth strengths, weaknesses, opportunities and threats (SWOT) assessment nor a formal assessment of the gaps or challenges that may place constraints on Indiana's agbioscience-based growth. That said, Battelle was generally exposed to the agbioscience ecosystem in the state through interviews with companies for the case study vignettes, and several observations can be made that may be helpful for CICP, BioCrossroads, and IFAII moving forward. Chief among these are discussed in Table 12.

Table 12. Preliminary Challenge Areas for Agbioscience Development and Potential Strategies and Actions for Further Consideration

Challenge Area	Potential Strategy and Action Considerations
Develop collaborations within innovation sectors	• Form key stakeholder subcommittees for each of the innovation sector opportunity areas: 1) plant science and crop protection; 2) value-added human food and nutrition products; 3) animal health and nutrition products, and 4) agricultural production equipment, processing equipment and precision agricultural systems. • Develop university/industry collaboration initiatives in targeted leading-edge areas where the state has assets but does not yet have a sufficiently robust position (such as precision agriculture). • Conduct frequent seminars and colloquia within Indiana related to each of the innovation sectors to encourage dialog on shared needs, emerging technology areas and opportunities, etc. • Encourage partnerships between Indiana companies that enhance global competitive advantage, such as the recent announcement by Elanco and Dow AgroSciences of a strategic R&D agreement that will focus on developing integrated solutions to enable livestock producers to increase meat and milk production to meet the demands of the growing global population. • Look for opportunities to connect Indiana's biomedical expertise to relevant agbioscience-based opportunities in functional foods, advanced nutrition and feed products, and veterinary medicine.
Improve the visibility of Indiana as a leading hub for agbioscience innovation	• Develop a brand for IFAII and launch the brand inside Indiana and externally. • Develop IFAII website to include brief listings of companies by key cluster/innovation sectors. • Attend major agbioscience/cluster-oriented conferences and events to promote Indiana agbiosciences. • Develop strategic relationships with international clusters focused in similar areas (a "cluster of clusters" approach).
Fill gaps in the innovation value-chain	• Perform interviews with the innovative agbioscience companies in the Battelle-developed database to identify major assets, resources, services, ingredients or components that these companies are having to source from out-of-state. • Develop a prioritized list of business recruitment candidates based on a review of individual and shared needs of Indiana innovative agbioscience companies. • Quantify volumes of agricultural commodities leaving Indiana in unprocessed form for opportunities to add further value in-state.
Facilitate the commercialization of new agbioscience innovations	• Perform outreach to existing agbioscience-oriented venture funds (e.g. Cultivian Sandbox Ventures) and angel investor groups in the United States to introduce Indiana opportunities. • Consider development of a dedicated seed/pre-seed fund for early stage proof of concept funding for agbioscience commercializable innovations. • Facilitate entrepreneurial access to business development assistance and specialized infrastructure and resources available in the state. • Work with industry and R&D centers to identify innovations and technologies that represent opportunities for commercialization—either with existing businesses or as new entrepreneurial business ventures. • Examine needs for specialized product development, piloting, and scale-up facilities to support emerging companies.

Challenge Area	Potential Strategy and Action Considerations
	• Develop an "entrepreneurial farmers" network comprised of farmers who are willing to experiment with new crops that have the potential to meet the needs of downstream value-added processors in the state.
Connect to broader, Midwest-regional agbioscience assets and initiatives	• Consider opportunities to pursue a broader Midwest agbioscience initiative leveraging assets and institutions in a multi-state region comprising states adjacent to Indiana (placing Indiana at its heart). • Examine opportunities for collaborations with major land-grant universities within the broader region to add expertise in areas that are complementary to existing Purdue capabilities.
Ensure adequate supply of a talented workforce	• Solicit input from industry regarding challenges in recruiting skilled personnel and facilitate discussions with regional higher education institutions to develop specialized courses or skills-development programs to fill needs. • Encourage temporary visiting appointments between industry and academe to gain better insight as to respective needs and interests.
Ensure access to specialized advisory services	• Identify, through discussions with industry, specific external service requirements in relation to agbiosciences in areas such as regulatory affairs, food safety, bio-containment, aseptic processing, capital access, legal affairs, etc. • Form a network of in-state experts in key areas and facilitate access to this network.

The above represent a tentative set of challenges and potential actions based on preliminary Battelle insights, but should be further tested and refined based on interviews or surveys conducted with innovative agbioscience stakeholder companies and institutions in Indiana and the input of the IFAII steering committee.

Conclusion

Indiana is among the leaders in the nation in life sciences, and agbiosciences represent an important element of Indiana's life science leadership. The full agbioscience value-chain is an important contributor to the health of the Indiana economy, providing over 133,000 jobs. Furthermore, it is a sector that is well-positioned for growth into the future because of the linkage between global grand challenges and potential agbioscience-based solutions.

Indiana benefits from a diversified and growing base of agbioscience R&D and associated innovation. In particular, Indiana has an opportunity to leverage existing assets to sustain growth and economic development across four primary innovation sectors: 1) plant science and crop protection; 2) value-added human food and nutrition products; 3) animal health and nutrition products, and 4) agricultural production equipment, processing equipment and precision agricultural systems. Each of these innovation drivers not only leverages R&D strengths within the state and existing industry presence, they also address very large-scale global market opportunities.

Appendix A. NAICS Codes Defining Agbiosciences

Segment	SubSegment	NAICS Code	NAICS Description
Ag & Biological Research, Testing, & Services	Biological and Agricultural R&D	54171AG	Biological and Agricultural R&D
	Testing Laboratories	541380AG	Testing Laboratories
	Veterinary Services	541940	Veterinary Services
Inputs to Production	Ag Machinery & Equipment	333111	Farm Machinery and Equipment Manufacturing
		333210	Sawmill and Woodworking Machinery Manufacturing
		333291	Paper Industry Machinery Manufacturing
		333294	Food Product Machinery Manufacturing
		423820	Farm/Garden Machinery and Equipment Merchant Wholesalers
	Agricultural Chemicals	325311	Nitrogenous Fertilizer Manufacturing
		325312	Phosphatic Fertilizer Manufacturing
		325314	Fertilizer (Mixing Only) Manufacturing
		325320	Pesticide and Other Agricultural Chemical Manufacturing
	Agricultural Inputs Wholesaling	424910	Farm Supplies Merchant Wholesalers
	Veterinary Medicines & Vaccines	325413AG	Pharmaceutical preparation manufacturing
Primary Production	Agricultural & Biomass Production	111	Crop production
		113	Forestry and logging
		1151	Support Activities for Crop Production
		1153	Support Activities for Forestry
	Livestock Production	112	Animal production
		1152	Support Activities for Animal Production
Agricultural & Biomass Processing	Agricultural Processing	311211	Flour Milling
		311212	Rice Milling
		311213	Malt Manufacturing
		311221	Wet Corn Milling
		311222	Soybean Processing
		311223	Other Oilseed Processing
		311225	Fats and Oils Refining and Blending
		311311	Sugarcane Mills
		311312	Cane Sugar Refining
		311313	Beet Sugar Manufacturing
	Biomass Processing	321113	Sawmills
		322110	Pulp Mills
		325193	Ethyl Alcohol Manufacturing
Food, Nutrition, & Health	Beverage Manufacturing	312111	Soft Drink Manufacturing
		312112	Bottled Water Manufacturing
		312113	Ice Manufacturing
		312120	Breweries
		312130	Wineries
		312140	Distilleries
	Botanicals, Diagnostics, and Biological Products	325411	Medicinal and Botanical Manufacturing
		325413	In-Vitro Diagnostic Substance Manufacturing
		325414	Biological Product (except Diagnostic) Manufacturing
	Food Processing & Manufacturing	3111	Animal Food Manufacturing
		3113	Sugar and Confectionery Product Manufacturing
		3114	Fruit/Vegetable Preserving and Specialty Food Manufacturing
		3115	Dairy Product Manufacturing
		3116	Animal Slaughtering and Processing
		3117	Seafood Product Preparation and Packaging
		3118	Bakeries and Tortilla Manufacturing
		3119	Other Food Manufacturing
		311230	Breakfast Cereal Manufacturing
Wholesaling, Distribution, & Storage Operations	Agricultural Commodity Wholesaling	42451	Grain & Field Bean Merchant Wholesalers
		42452	Livestock Merchant Wholesalers
		424590	Other Farm Product Raw Materials Merchant Wholesalers
	Food Product Wholesaling	424430	Dairy Product Merchant Wholesalers
		424440	Poultry Product Merchant Wholesalers
		424470	Meat And Meat Product Merchant Wholesalers
		424480	Fruit And Vegetable Merchant Wholesalers
	Warehousing and Storage	493120	Refrigerated Warehousing & Storage
		493130	Farm Product Warehousing & Storage

Note: NAICS codes with the "AG" suffix have been modified using Economic Census data to estimate the agricultural-based share of the NAICS employment.