

EXECUTIVE SUMMARY

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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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 (IFAI) 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 IFAI 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 state¹. 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 quotients² (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	Specialization	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%

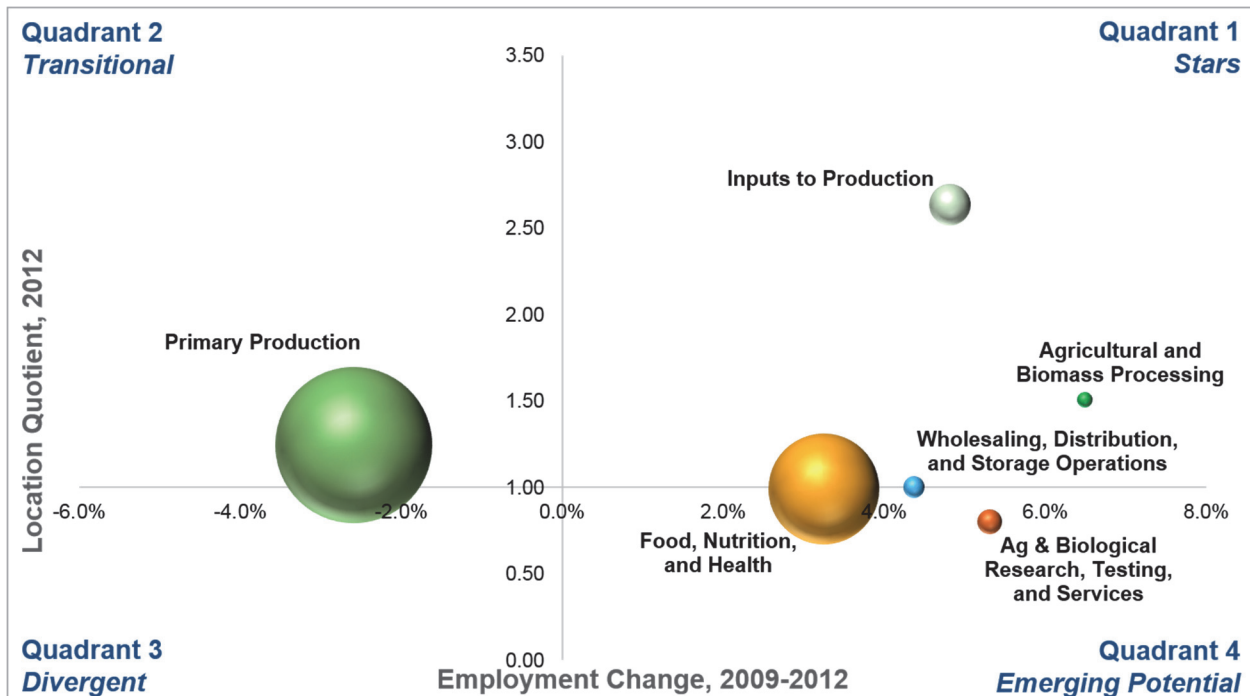
Source: Battelle analysis of Bureau of Labor Statistics, QCEW data from IMPLAN, farm proprietor employment data from the Bureau of Economic Analysis, and farm proprietor establishment data from USDA NASS.

* 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	<ul style="list-style-type: none"> • 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
	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Develop a brand for IFAll and launch the brand inside Indiana and externally. Develop IFAll 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> • 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 IFAll 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.