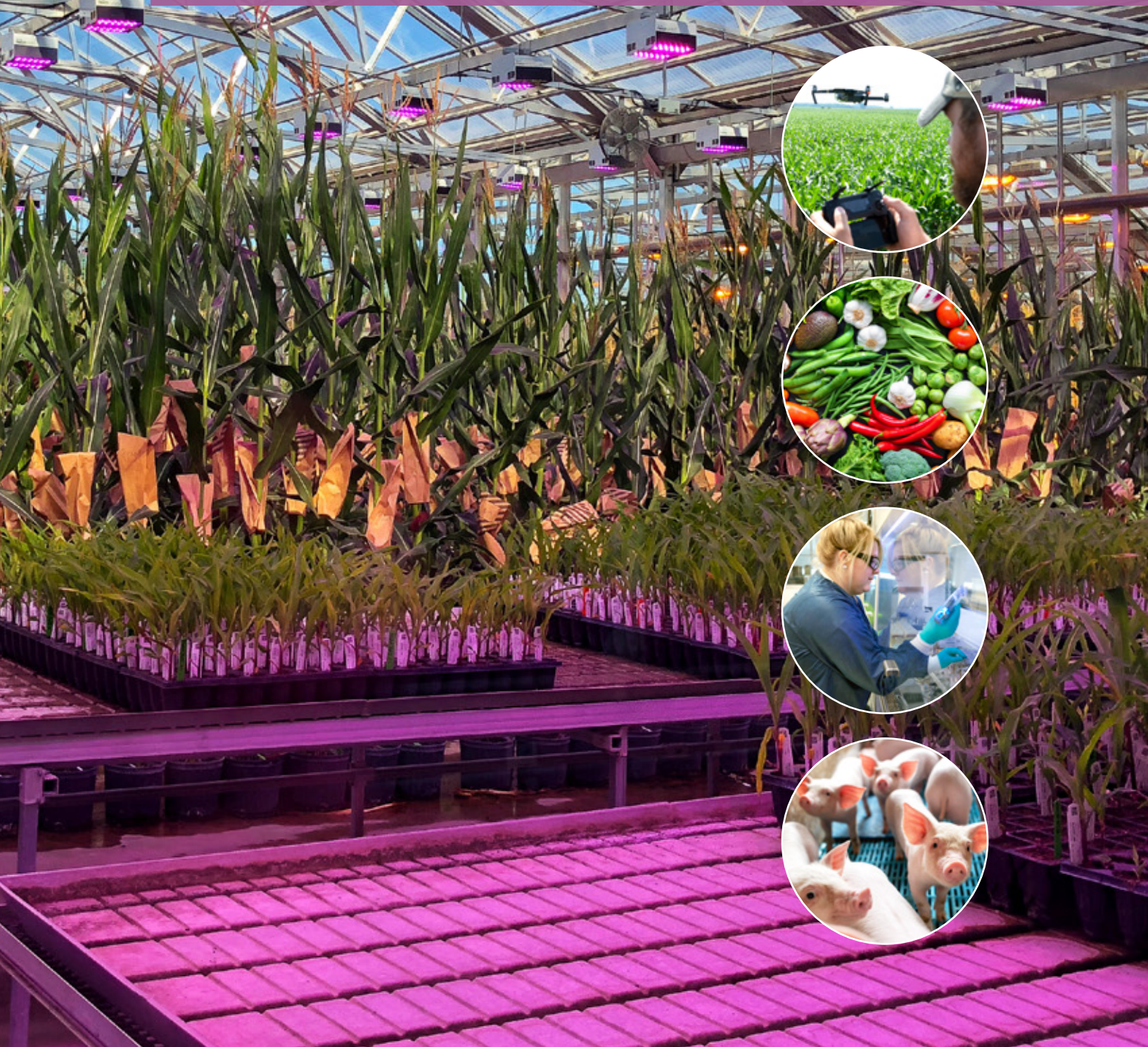


Innovative Agbioscience in Indiana: 2020 Assessment

Prepared by: TEconomy Partners, LLC

Submitted to: AgriNovus Indiana

November 2020





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Executive Summary

States and regions must make deliberate choices in terms of where they invest their time and financial resources for economic development. Cluster-based economic development is a proven practice whereby efforts are focused toward advancing industry sectors that show established or emerging strengths in a state or region and that demonstrate a line-of-sight to large-scale and expanding markets. It is very much supported by innovation-based economic development, which seeks to build robust ecosystems of research and development (R&D) and commercialization that support the ongoing competitiveness of existing industries and advance entrepreneurship and new business development.

In a 2015 report, *Innovative Agbioscience in Indiana: A Baseline Assessment*, it was found that the agbiosciences represented a cluster of Indiana economic activity rooted in established and emerging strengths and associated with large-scale market opportunities. The report was foundational in examining the agbiosciences as a focused innovation cluster for Indiana's economic development efforts. The report provided strategic guidance for the development, mission objectives, and initial programming of AgriNovus Indiana.

Since the initial 2015 assessment, Indiana has further cemented its leadership position in the agbiosciences. Recognizing the power and promise of the sector for advancing economic development in the state, AgriNovus Indiana and its regional and statewide partners are pursuing a series of initiatives and programs designed to enhance awareness of agbioscience opportunities in Indiana, convene stakeholders to advance unique collaborations, promote entrepreneurship and new agbioscience business growth, increase access to capital, and build a science, technology, engineering, and mathematics (STEM) workforce to meet labor demands.

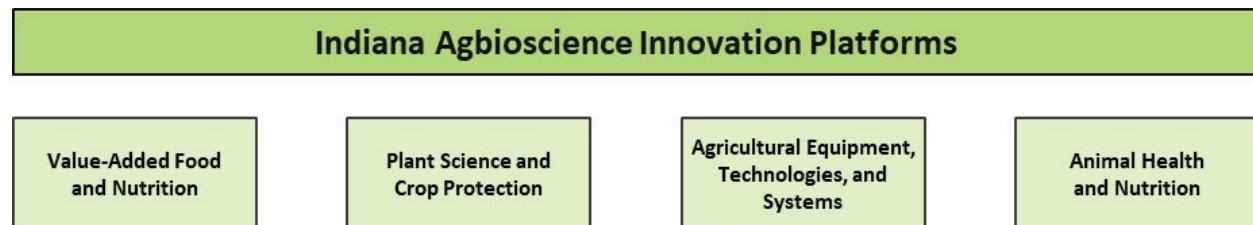
However, since 2015, various factors have generated changes in agriculture and its associated value chains, including forces that may impact the Indiana agbioscience environment. With a mix of positive and negative developments impacting the agbiosciences globally, it is prudent to update the prior analysis and examine the sector's promise for ongoing development in the state. This report performs these analyses.

Overall, the report finds that the agbiosciences continue to represent an extremely important component of Indiana's economy. The sector is driven by an R&D ecosystem in Indiana comprising university R&D (especially, but not exclusively, at Purdue University) and major industrial R&D operations. The Indiana agbioscience sector delivers products and services into an expanding global marketplace and is driven by four innovation-based platforms (Figure ES-1):

- **Value-Added Food and Nutrition**—working to add value to basic agricultural commodities by changing or transforming a product from its original state to a more valuable, further-processed state. The focus of this innovation platform is on downstream, post-farmgate processing of agricultural output into value-added food, nutrition, and health products.
- **Plant Science and Crop Protection**—enhancing the productivity of production agriculture by: creating crops with higher yields, resistance to stress, and resistance to pests and plant diseases; introducing crop varieties with enhanced functional characteristics; and developing targeted crop protection chemicals, fertilizers, soil inoculants, and other chemical and biologic inputs to production.

- **Agricultural Equipment, Technologies, and Systems**—encompassing the specialized equipment for crop and livestock production, materials handling and storage, agricultural distribution, and agricultural processing operations, as well as technologies focused on the integration of digital tools and analytics into agricultural production systems.
- **Animal Health and Nutrition**—providing basic and 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.

Figure ES-1: Indiana Agbioscience Innovation Platforms



Source: TEconomy Partners, LLC.

Within Indiana, the companies supported/enhanced by the four innovation platforms along with agricultural production and distribution is a sizeable component of the state's economy. Total agbioscience employment in Indiana exceeded 146,000 workers (and proprietors) in 2018 and grew by 5.4 percent since 2012. Though recent growth slowed in comparison with the 2012–2015 period, it nonetheless stayed positive in the recent 2015–2018 period (Table ES-1).

Table ES-1: Employment and Employment Growth of Indiana's Agbioscience Platforms (2012–2018)

Innovation Platform	Employment			% Employment Change		
	2012	2015	2018	2012–2015	2015–2018	2012–2018
Agricultural Production and Distribution	69,457	70,357	69,431	1.3%	-1.3%	0.0%
Value-Added Food and Nutrition	46,737	50,611	53,393	8.3%	5.5%	14.2%
Plant Science and Crop Protection	7,799	7,548	6,584	-3.2%	-12.8%	-15.6%
Agricultural Equipment, Technologies, and Systems	5,189	5,756	5,474	10.9%	-4.9%	5.5%
Animal Health and Nutrition	9,531	10,030	11,305	5.2%	12.7%	18.6%
Total Indiana Agbioscience Industry	138,713	144,302	146,187	4.0%	1.3%	5.4%

Source: TEconomy analysis.

It is important to note that employment tells only one side of the story of economic impact. With ever increasing global pressures and competition, the economic output of Indiana’s agbioscience industry is as important if not more important an economic measure. To assess the economic performance and impact of the Indiana agbioscience platforms, IMPLAN input/output analysis was used. Table ES-2 shows the output estimated by the IMPLAN model for all three periods in 2018 dollars to better understand the real (versus inflationary) change over time. Among the Indiana platforms, four platforms exhibited “real” output growth over the 2012–2018 period, with three showing real output growth in the more recent 2015–2018 period.

Table ES-2: Estimated Output and Real Change in Output of Indiana’s Agbioscience Platforms (2012–2018)

Innovation Platform	Output (in 2018 dollars; \$M)			% Real Output Change		
	2012	2015	2018	2012–2015	2015–2018	2012–2018
Agricultural Production and Distribution	\$12,547.1	\$12,230.8	\$13,051.0	-2.5%	6.7%	4.0%
Value-Added Food and Nutrition	\$25,758.0	\$28,231.8	\$29,103.4	9.6%	3.1%	13.0%
Plant Science and Crop Protection	\$5,441.3	\$5,436.5	\$3,979.0	-0.1%	-26.8%	-26.9%
Agricultural Equipment, Technologies, and Systems	\$1,618.9	\$2,021.3	\$1,872.2	24.9%	-7.4%	15.6%
Animal Health and Nutrition	\$3,960.5	\$4,036.7	\$4,301.2	1.9%	6.6%	8.6%
Total Indiana Agbioscience Industry	\$49,325.7	\$51,957.1	\$52,306.8	5.3%	0.7%	6.0%

Source: TEconomy analysis using IMPLAN 2018 State of Indiana model. Note: columns may not sum due to rounding.

Ultimately, AgriNovus Indiana focuses its efforts on working with partners across the state to create the conditions necessary to fuel the growth of Indiana’s agbioscience sector, ensuring its long-term economic sustainability and global competitiveness. While the input/output models allow for an estimation and examination of platform-specific output, the overall economic value or impact to the state of each platform, and ultimately the entire Indiana agbioscience industry, can also be assessed.

Table ES-3 summarizes the current importance of Indiana’s innovative agbioscience platforms to the Indiana economy both directly and through the multiplier effect that the industry has on other Indiana industry sectors. **Taken together, the agbiosciences combine to generate and support a total economic impact within the state of Indiana of nearly \$76 billion in 2018.** In terms of the agbiosciences contribution to the gross state product (GSP) of Indiana, the industry accounts for nearly \$15 billion in direct contribution and ultimately supports over \$27.5 billion in state GDP.

Table ES-3: Economic Impact of Indiana's Total Agbioscience Industry (2018)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	State/Local Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	146,187	\$6,664.54	\$14,945.21	\$52,306.75	\$912.87	\$1,394.89
Indirect Effect	75,737	\$4,804.69	\$7,302.15	\$14,374.71	\$601.97	\$912.48
Induced Effect	65,764	\$3,146.00	\$5,338.38	\$9,281.49	\$494.82	\$629.93
Total Impact	287,689	\$14,615.24	\$27,585.73	\$75,962.95	\$2,009.66	\$2,937.29
Multiplier	1.97	2.19	1.85	1.45		

Source: TEconomy analysis using IMPLAN 2018 State of Indiana model. Note: columns may not sum due to rounding.

The impact of the agbiosciences on Indiana's economy reflects the important role of AgriNovus Indiana and its regional partners as a signature economic development initiative. Indiana is experiencing agbioscience-based economic growth; and in three out of four AgriNovus target agbioscience platforms, there has been robust growth in employment and output impacts generated for Indiana. While Plant Science and Crop Protection has experienced a downturn in recent years in terms of its comparative performance, it is important to note that this cluster nationally has experienced business consolidations and employment rationalizations through significant merger and acquisitions activity. Into the future, all four agbioscience platforms in Indiana appear well positioned to grow as a result of its strengths in R&D, innovation, and other assets, and their line-of-sight to significant market growth opportunities.

This is evidenced, in part, by the number of recent agbioscience-related economic development announcements, which include:

- Solinftec moving its global headquarters to Indiana and raising an additional \$60 million in venture capital.
- Inari expanding its footprint in Indiana as a result of an \$89 million venture capital investment announced in 2019.
- Italtipollina's development of a \$6.8 million R&D center focused on the production of organic fertilizers, biostimulants, and microbials.
- Mission Foods' plans to establish a manufacturing plant in Indiana, creating 544 new jobs when it opens.
- Premier BioSource's development of the company's first Indiana operation focusing on swine production for biomedical research and product development.
- Greenleaf Foods' plans to construct North America's largest plant-based protein manufacturing facility in Indiana, creating 460 jobs when it becomes operational.
- EnviroKure, a Pennsylvania-based producer of biologic amendments and organic fertilizers, decision to invest more than \$10 million to build a full-scale manufacturing plant in Indiana.
- Cormo USA Inc., a joint venture between Switzerland-based Cormo AG and Florida-based Sustainable Projects Group Inc., investment of approximately \$29.5 million to establish in Indiana its first U.S. production plant creating, 250 jobs.

With global population expanding and global wealth increasing, the agbiosciences is an industry that will continue to experience growth. Humanity needs to find solutions that will allow farmers to produce more food on their existing farmland. Indiana’s scientists, technologists, and engineers are on the frontlines working to meet this grand challenge—using modern tools and advancements in biological sciences, physical sciences, computation, data sciences, advanced analytics, and other disciplines to increase agricultural yields; improve resource use efficiencies; enhance environmental resiliency; and develop new, sustainable, value-added uses for farm outputs. As a result, Indiana’s agbioscience sector is well positioned to generate significant economic impact for the state’s economy in the future.

Chapter I. Introduction

The Agbiosciences—An Ongoing Development Opportunity

States and regions must make deliberate choices in terms of where they invest their time and financial resources for economic development. Cluster-based economic development is a proven practice, whereby economic development is focused toward advancing agglomerated industry sectors that show established or emerging strengths in a state or region and that demonstrate a line-of-sight to large-scale and expanding markets. It is very much supported by innovation-based economic development, which seeks to build robust ecosystems of research and development (R&D) and innovation commercialization that support the ongoing competitiveness of existing industries and advance entrepreneurship and new business development.

In the 2015 report, *Innovative Agbioscience in Indiana: A Baseline Assessment*, it was found that innovative agbiosciences represented a cluster of Indiana economic activity rooted in established and emerging strengths and associated with large-scale market opportunities. It was further found that the sector was supported by an R&D ecosystem in Indiana comprising university R&D (especially, but not exclusively, at Purdue University) and major industry R&D operations. It was noted that the sector delivers products and services into an expanding global marketplace and demonstrated particularly sound fundamentals for advancing innovation-based economic development in Indiana across multiple platforms in the following:

- Value-Added Food and Nutrition
- Plant Science and Crop Protection
- Agricultural Equipment, Technologies, and Systems
- Animal Health and Nutrition.

While the structure of international agriculture markets has changed in the past five years (most notably in terms of trade barriers and tariff expansion), the fact remains that global demand for food and sustainable agricultural products will continue to rise. The fundamental drivers of ongoing demand (increasing global populations and rising levels of global income) have not changed, and thus the original Battelle commentary on this environment still holds true:

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. 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.¹

For 2020 and into the foreseeable future, the fundamental need remains for advancing agricultural innovation as a solution to increasing global food demands, while also addressing associated environmental pressures. It is clear that the need and opportunity for agricultural innovation to meet global grand challenges will continue as humanity seeks to address large-scale issues, including the following:

- How to meet the nutritional needs of a rapidly expanding global population, and how to do so without degrading finite agronomic land or causing further deforestation.
- How to expand the use of renewable and sustainable resources and move away from economies dependent on nonrenewable resources and generating waste.
- How to address the challenges of global climate effects, water resource depletion, pollution and the proliferation of toxins and contaminants from human activity.
- How to create enhanced economic opportunities and generate sustainable economic development.

Through the application of scientific and technological advancements, innovation is occurring that refines existing products and practices to address these issues and opportunities. Furthermore, innovations are resulting in pathways to new products, product and service categories, and novel entrepreneurial business ventures.

Convergence in Agbioscience

One of the key business trends that has significantly accelerated since 2015 is the phenomenon of “convergence.” Convergence refers to an observed trend for innovation to increase at the interface between distinct disciplines or fields in science, engineering, and technological development. Opportunities arise through integration of multiple digital, physical, and biological domain elements to derive new products and new solutions to market needs. Companies known for work in one sector may partner with or acquire entities in another to develop multicomponent systems and novel combinatorial innovations.

In a report for the Central Indiana Corporate Partnership (CICP), TEconomy notes that convergence is being experienced in agbioscience:

This cluster is likely to experience significant change from multiple forces. Convergence is occurring between traditional biological-inputs providers (seed and agrichemicals), agricultural equipment manufacturers, and IT/informatics companies working to deliver packaged digital and precision agriculture solutions to producers. This model seeks to increase production yields through highly precise spatial diagnosis of field conditions combining real-time sensing and predictive analytics delivered through both on-equipment and remote cloud-based systems. Indiana companies are already engaging in development of strategic partnerships and taking part in acquisitions activity.

TEconomy Partners, LLC. 2018. *Clusters and Disruptors: Envisioning Central Indiana’s Economic Future in a Time of Change.*

¹ Battelle Technology Partnership Practice and BioDimensions. Impact and Innovation: Agbioscience in the Southern United States. 2013.

A Need to Update Indiana's Agbioscience Analysis

Since 2015, various factors have generated change in agriculture and its associated value chains, including forces that may impact the Indiana agbioscience environment. Examples include the following:

- Advancements in science and in innovative technologies such as gene editing (CRISPR) and high-throughput sequencing.
- New and emerging business models and practices, such as the phenomenon of convergence (see sidebar).
- Changing consumer preferences that impact agricultural products, including further growth in organic food demand and the local foods movement.
- Increasing concerns over climate change and other factors that may be influencing the emergence and spread of pathogens impacting plant and animal health.
- Increasing prevalence of trade disputes and tariffs distorting market dynamics in key agricultural commodities.

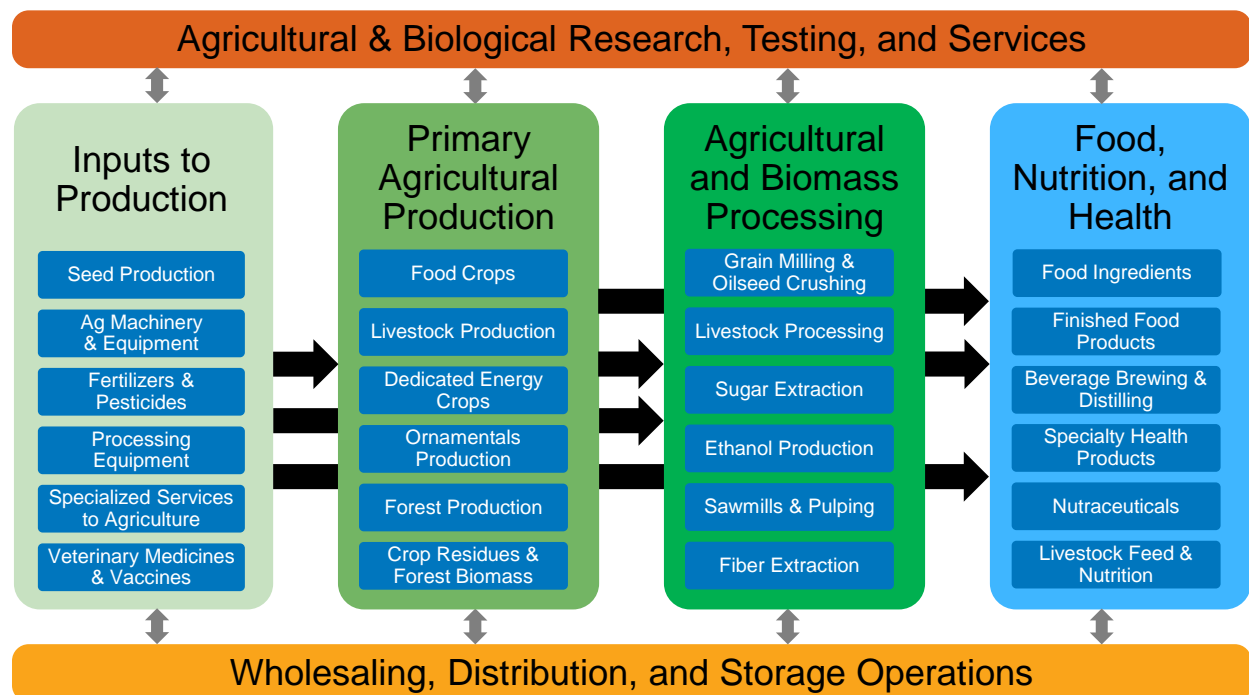
With a mix of positive and negative developments impacting the agbiosciences, as shown above, it is certainly prudent to perform a situational analysis of the agbiosciences in Indiana and renew examination of the sector's promise for ongoing development in the state. Furthermore, AgriNovus Indiana determined that with more than five years now passed since the original 2015 study, the timing is right to perform an assessment of progress that has occurred and the ongoing promise of the agbiosciences as an Indiana economic driver moving forward. This report performs these analyses, providing in-depth assessment of progress made, opportunities for the future, and emerging domestic and international competition in agbioscience-based state and regional development.

Defining "Agbioscience"

To maintain consistency in analysis, the same structural definition for "agbioscience" is deployed as used in the 2015 project. The agbiosciences represent an applied area of scientific knowledge and innovation—a (primarily) life-science-oriented sector engaging R&D to improve, protect, and expand primary agricultural production and the production of value-added products based on agricultural outputs.

The agbioscience sector comprises 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



Source: TEconomy Partners, LLC.

As noted in the 2015 report, the agbiosciences represent a dynamic, high-opportunity sector for economic development based on several key characteristics:

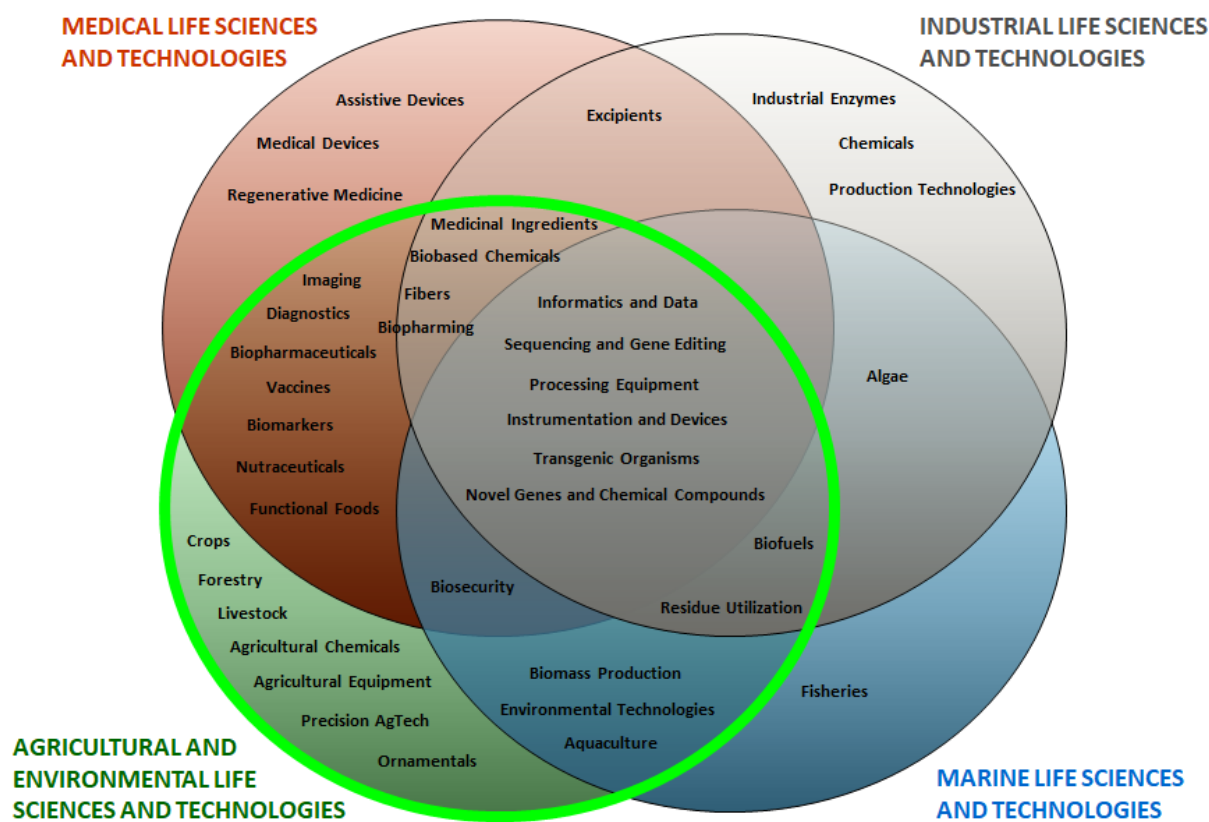
- The agbiosciences provide opportunities for business growth in the development of advanced products and technologies for use within the sector itself—technologies such as advanced seed, crop protection agents, agricultural equipment, animal health and nutrition products, advanced decision support systems, etc.
- The agbiosciences leverage an established base of specialized U.S. university capabilities (especially within land-grant universities) and federal United States Department of Agriculture Agricultural Research Service (USDA-ARS) 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 and for R&D operations of major international agribusiness companies. 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.
- 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 (especially in urban and suburban metro areas), the agbiosciences build upon a geographically distributed production environment and represent one of the few high-tech sectors demonstrating a robust impact on rural America.

Indiana Life Science and Industrial Diversity—An Advantage in a Convergence Economy

One of the key trends in both scientific research and in commerce is the phenomenon of convergence. There is a distinct advantage for Indiana in having a diversity of life science (and other technological, digital, and manufacturing) industries present in the state that may collaborate to leverage convergence opportunities. The 2015 report actually predicted that the diversity of capabilities in Indiana would prove advantageous, noting as follows:

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



Source: TEconomy Partners, LLC.

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. In recognition of this, the Central Indiana Corporate Partnership (CICP) developed and operates AgriNovus Indiana to promote further advancement of the agbioscience ecosystem and BioCrossroads to advance biomedical life sciences.

AgriNovus Indiana and Indiana's Agbioscience Innovation

The work of AgriNovus Indiana focuses on “innovative agbioscience,” that is, the upstream and downstream sectors that provide valuable products and services that enhance agricultural production and convert agricultural output into higher-value processed products. As such, AgriNovus Indiana works to promote and accelerate the growth of the agbioscience community across two primary dimensions:

- **Inputs to primary agricultural production**—e.g., advanced crop varieties and seeds, crop and livestock protection products, soil amendments, and precision agricultural technologies.
- **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, and health; materials; chemicals; polymers; textiles; and other specialized industrial and consumer markets.

AgriNovus Indiana works to create and enhance conditions that are favorable to ongoing agbioscience innovation and commercial operations. Thus, the organization is engaged in promoting growth in Indiana agbioscience research and development (across university, institutional, and private sector R&D performers), enhancing opportunities to translate innovations into commercial products and services to grow the economy, and ensuring that the operational ecosystem in Indiana has access to the specialized resources it requires for growth (in terms of skilled personnel, capital, infrastructure, facilities, and favorable policies).

Structure of Report

The original 2015 Battelle report was foundational in establishing a baseline situational assessment for the agbiosciences in Indiana. The report examined the economic performance of the primary subsectors composing the agbioscience sector in Indiana (establishments, employment, growth rate, etc.) and examined the operational environment for agbioscience in the state. R&D specializations within Indiana organizations were identified and connected to “development platforms” that represented line-of-sight to significant market opportunities. A series of strategic recommendations for initial areas of focus for AgriNovus Indiana were provided. The work focused specifically on those innovative agbioscience economic activities that bracket (but do not include) primary agricultural production. Certainly, it was noted that 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) developed by farmers and agricultural experiment stations, for example—but the study focus was firmly directed toward technology-based economic development and its ability to generate new employers and enhanced business growth. As such, the focus of the project was 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. The 2020 project herein takes this same approach.

The structure of this report is similar to the 2015 document, although enhanced through having the ability to compare recent data with the previous study to track change. Additional analysis has also been performed that includes the following:

- Assessment of the innovative agbioscience economy in three Indiana regions that have placed an emphasis on advancing sector growth—working to identify progress that has been made on a regional level to advance the Indiana agbiosciences. Appendix A provides an examination of the performance and assets in the three regions.
- Evaluation of **domestic and international locations** that are also emphasizing the agbiosciences as a focus area for innovation-based economic development (i.e., competitors or potential competitors for Indiana). While Indiana has made considerable headway in advancing the agbioscience innovation economy across the state, and gaining visibility for it, it is not alone in pursuit of advancing agbioscience R&D, innovation, and talent development as an economic engine. This report benchmarks several key competing regions, their primary focus areas, and considers Indiana’s comparative position and advantages.

Chapter II provides quantitative summary statistics for the overall agbioscience and agriculture value chain in Indiana (irrespective of the degree of innovation occurring in individual component areas of the value chain) **and the principal subsectors that compose this value chain.** Data are examined for employment, number of business establishments, average wage levels, and change in employment. Also quantified in this analysis is the location quotient for each subsector, which measures the degree of Indiana’s comparative specialization in each subsector. As before, the analysis in Chapter II uses North American Industry Classification System (NAICS) codes as the basis for the analysis as outlined in Appendix B.

In Chapter III, the report focuses on the agbioscience R&D and innovation environment in Indiana, reviewing trends in research funding overall, research publishing in disciplines and fields relevant to agbioscience, and intellectual property (IP) generation. An in-depth cluster analysis of published research is also provided, allowing for comparison of current clusters with previous clusters identified in the original report. Appendix C examines risk capital flows to agbioscience business ventures.

Chapter IV provides an assessment of the performance across designated innovative “development platforms.” These include the platforms that AgriNovus Indiana has been engaged in promoting based on the platform recommendations from the original Battelle research and as directed by the AgriNovus Indiana board. Consideration is given in this chapter to whether adjustments to the platforms may be considered based on the research findings and whether any new or emerging platforms should be highlighted for further consideration.

Chapter V provides input/output analysis of the economic impact of the agbiosciences in Indiana. Specific details are provided for the estimated impacts across four development platforms and production agriculture.

Chapter VI provides a synopsis of benchmarking analysis, whereby TEconomy examines the focus and activities of competing, or potentially competing, agbioscience development initiatives domestically and internationally.

Chapter VII summarizes conclusions based upon the full findings of the 2020 project.

Chapter II. Indiana's Agbioscience Profile

Introduction—Data and Methodology

The following economic analysis examines Indiana's agbioscience composition from 2015–2018 (with 2018 being the most recent full year for available data). The analysis 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 NAICS.²

For the employment analysis, TEconomy uses Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) program data. The QCEW data are the most current, detailed state- and county-level industry establishment, employment, and wage figures available.³ 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 unemployment insurance (UI) laws and federal workers covered by the Unemployment Compensation for Federal Employees (UCFE) program.⁴ TEconomy utilizes an "enhanced" version of these state and county data purchased from IMPLAN, a private vendor.

It is important to note that QCEW data do not include many workers on small farms. The program data are collected from unemployment insurance records and do not cover self-employed farmers and some wage and salary farm workers. Because small farms and their workforce contribute significantly to Indiana's farm economy, TEconomy sources other data to account for this farm-related activity. Economic data on family farms and their employment are tracked by the Economic Research Service (ERS) of the U.S. Department of Agriculture (USDA) and the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. The USDA's National Agricultural Statistics Service (NASS) also publishes

² The North American Industrial Classification System (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 subsectors appears in Appendix B.

³ 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.

⁴ 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.

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 for the number of self-employed farm proprietors are used extensively in this report. County, state, and national estimates are available through 2018. 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 provide a detailed overview of the entire agricultural production industry in Indiana.

Size and Performance of Indiana's Agbioscience Industry

Table 1 provides comparative data for 2015 and 2018, both for the agbioscience sector as defined overall and for its primary segments and subsectors.

For the agbiosciences overall, Indiana employment expanded moderately from 2015–2018, rising from 141,514 jobs in 2015 to 142,358 jobs in 2018 (a 0.6 percent growth in employment). These figures include on-farm employment (farm proprietors within Primary Production). If these farm proprietors are removed from the equation, the employment growth picture changes more positively, with 2015 showing 90,734 jobs and 2018 showing 93,174 jobs, a growth rate of 2.7 percent. In both cases, however, Indiana's growth in agbioscience employment overall lagged behind national growth in agbioscience, which from 2015–2018, stood at 3.5 percent (including farm proprietors) and 6.0 percent (excluding farm proprietors). It is also apparent that **growth in agbioscience employment has slowed in Indiana**, with the agbiosciences overall growing at 5.7 percent for 2012–2015, but only at 0.6 percent for 2015–2018.

It is also notable that employment growth for 2015–2018 for the agbiosciences, with or without the inclusion of farm proprietors, lagged Indiana's total private-sector growth over that same time period (4.2 percent). Looking back further, and examining 2012 through 2018 performance, agbioscience employment (not including farm proprietor employment) outpaced total Indiana private-sector growth, with the former rising by 12.6 percent for 2012–2018 and the latter by 10 percent.

Measuring Indiana's Agbioscience Industry

The employment numbers presented in this chapter are developed around key agbioscience NAICS codes supplemented by a measure of farm proprietors to better represent the employment in the primary production segment. It should be noted that these employment numbers, including total agbioscience employment estimates, will differ from Chapter V employment numbers due to three primary reason:

- 1) Employment estimates also include small numbers of proprietors in sectors beyond primary production.
- 2) Employment estimates are built around the requirements of an economic impact model including allocating the "farm proprietors" number to the individual economic sectors that make up agricultural primary production.
- 3) Employment estimates also include employment for firms that are part of the encompassing Indiana agbioscience industry whose NAICS codes fall outside of the core agbioscience sectors (e.g., firms in the computer programming or software development sectors focused on precision agriculture applications).

Due to these important considerations and inclusions, the "total" employment figures represented in this Chapter II analysis are somewhat smaller and not completely comparable with the total Indiana agbioscience employment figures provided in the Chapter V analysis.

Table 1: Indiana Agbioscience Industry Segment and Subsector Detail

AgBioscience Segment and Subsector	2012 Metrics		2015 Metrics		2018 Metrics				Recent Indiana Employment Performance			Recent U.S. Employment Performance		
	Estabs.	Employ.	Estabs.	Employ.	Estabs.	Employ.	Avg. Wage	Special-ization (LQ)	Change, 2012-2015	Change, 2015-2018	Change, 2012-2018	Change, 2012-2015	Change, 2015-2018	Change, 2012-2018
Ag/Bio Research, Testing, & Services**	704	8,142	708	8,391	730	9,292	\$46,827	1.06	3.1%	10.7%	14.1%	11.1%	12.9%	25.5%
Biological and Agricultural R&D**	26	1,056	27	660	30	667	\$178,747	3.68	-37.5%	1.0%	-36.8%	6.2%	6.1%	12.6%
Veterinary Services	641	6,681	644	7,265	659	8,103	\$35,156	0.98	8.7%	11.5%	21.3%	11.6%	13.4%	26.5%
Testing Laboratories (Ag/Bio/Food)	36	405	37	465	40	521	\$59,382	1.71	14.9%	12.0%	28.7%	3.4%	4.5%	8.1%
Inputs to Production**	771	13,019	752	13,069	815	11,198	\$68,754	1.67	0.4%	-14.3%	-14.0%	1.2%	-0.7%	0.5%
Ag Machinery & Equipment	310	4,903	303	4,979	340	4,614	\$57,378	1.34	1.6%	-7.3%	-5.9%	2.0%	-3.2%	-1.2%
Agricultural Chemicals**	21	2,284	24	2,373	33	1,022	\$87,037	1.34	3.9%	-56.9%	-55.3%	0.0%	-2.2%	-2.2%
Agricultural Inputs Wholesaling	437	4,481	422	4,534	439	4,314	\$60,934	1.72	1.2%	-4.9%	-3.7%	5.0%	2.1%	7.2%
Veterinary Medicines & Vaccines**	3	1,351	3	1,183	3	1,248	\$122,866	6.31	-12.4%	5.5%	-7.6%	0.0%	1.3%	1.4%
Primary Production (Corp + Proprietors)	58,700	65,046	57,600	65,517	56,100	64,472	\$40,118	1.07	0.7%	-1.6%	-0.9%	1.5%	-0.8%	0.6%
Agricultural & Biomass Production	1,048	7,436	1,184	7,679	1,293	8,040	\$41,495	0.39	3.3%	4.7%	8.1%	4.2%	0.3%	4.5%
Livestock Production	508	6,436	563	7,058	606	7,248	\$38,590	1.15	9.7%	2.7%	12.6%	7.7%	4.1%	12.1%
Farm Proprietors*	57,144	51,174	55,853	50,780	54,201	49,184	N/A	1.39	-0.8%	-3.1%	-3.9%	-0.8%	-2.1%	-2.9%
Agricultural & Biomass Processing	139	4,904	141	4,844	145	5,349	\$65,953	1.57	-1.2%	10.4%	9.1%	6.7%	0.4%	7.1%
Agricultural Processing	26	2,839	25	2,844	30	2,929	\$76,035	2.26	0.2%	3.0%	3.2%	3.8%	2.1%	6.0%
Biomass Processing	113	2,065	116	2,000	115	2,420	\$53,752	1.15	-3.2%	21.0%	17.2%	8.6%	-0.7%	7.9%
Food, Nutrition, & Health	602	36,009	666	42,729	782	45,425	\$51,189	1.12	18.7%	6.3%	26.1%	5.7%	9.6%	15.8%
Beverage Manufacturing	93	3,913	140	4,652	202	5,858	\$41,662	1.04	18.9%	25.9%	49.7%	18.9%	25.6%	49.3%
Drugs & Diagnostics	15	394	16	3,121	23	3,185	\$114,903	1.62	692.1%	2.1%	708.4%	20.1%	17.6%	41.2%
Food Processing & Manufacturing	494	31,702	510	34,956	557	36,382	\$47,146	1.10	10.3%	4.1%	14.8%	3.3%	6.8%	10.3%
Wholesaling, Distribution, & Storage Operations	384	6,768	342	6,964	357	6,622	\$50,190	0.89	2.9%	-4.9%	-2.2%	4.9%	7.1%	12.4%
Agricultural Commodity Wholesaling	204	2,434	186	2,521	187	2,124	\$50,582	1.39	3.6%	-15.7%	-12.7%	1.5%	-4.0%	-2.5%
Food Product Wholesaling	139	2,306	116	2,316	133	2,385	\$52,268	0.56	0.4%	3.0%	3.4%	4.9%	9.3%	14.6%
Warehousing and Storage	41	2,028	40	2,127	37	2,113	\$47,450	1.32	4.9%	-0.7%	4.2%	8.8%	13.9%	23.9%
State of Indiana AgBio Industry														
Corporate Only Total	4,156	82,715	4,357	90,734	4,728	93,174	\$51,825	0.99	9.7%	2.7%	12.6%	5.7%	6.0%	12.0%
State of Indiana AgBio Industry														
Corporate and Proprietor Total	61,300	133,888	60,209	141,514	58,929	142,358	N/A	1.07	5.7%	0.6%	6.3%	3.6%	3.5%	7.2%
Total Private Sector	154,603	2,418,211	154,076	2,551,090	162,522	2,659,185	\$47,864	1.00	5.5%	4.2%	10.0%	6.9%	5.3%	12.6%

Source: TEconomy analysis of BLS, CEW enhanced data from IMPLAN, Farm Proprietor employment data from BEA, and Farm Proprietor establishment data from USDA NASS 2018 Agricultural Survey.

* Comparable average wage estimate is not available for farm proprietors.

**Change in Agricultural Chemicals appears to be primarily due to reclassification of Dow AgroSciences when Corteva formed. It appears at least some employment was moved from ag chemicals to corporate/regional headquarters.

The picture changes when examining individual segments of agbioscience. **The R&D-focused segment of Ag/Bio Research, Testing, and Services grew employment by a robust 10.7 percent for 2015–2018,** versus 3.1 percent for 2012–2015. In 2012, this segment had a low (nonconcentrated) location quotient (LQ) of 0.80 that indicated that the segment was not considered to concentrated in Indiana; but, for 2018, the LQ has risen to 1.06, moving into “concentrated” territory.⁵

The Agricultural and Biomass Processing segment also improved performance. Between 2012 and 2015, the segment lost employment (-1.2 percent); but, for 2015–2018, it rebounded, demonstrating 10.4 percent growth (adding 505 jobs) and, in 2018, demonstrated a LQ of 1.57. **Food, Nutrition, and Health also saw employment rise by 6.3 percent (adding 2,696 jobs)** for 2015–2018 and had a 1.12 LQ.

Between 2015 and 2018, **the Wholesaling, Distribution, and Storage Operations segment lost jobs,** reducing employment from 6,964 jobs in 2015 to 6,622 in 2018 (a 4.9 percent drop). The segment is not a specialization for Indiana, with an LQ of 0.89.

The important Inputs to Production segment recorded a fairly significant decline in employment, with the total of 13,069 jobs in 2015 dropping to 11,198 jobs in 2018 (a loss of 1,871 jobs or a 14.3 percent job reduction). Of these job losses, 1,351 were recorded in the Agricultural Chemicals subsector (which showed a 56.9 percent reduction in subsector employment for 2015–2018); but, TEconomy cautions that the apparent decline may be a result of NAICS code reclassification of Corteva Agriscience. **While Inputs to Production shows a job loss, it is still the most specialized segment of the agbiosciences for Indiana, with a strong LQ of 1.67.**

Figures 3 through 6 provide further analytical perspective on numbers shown in Table 1, placing segments and subsectors on quadrants measuring concentration (LQ) and employment growth.

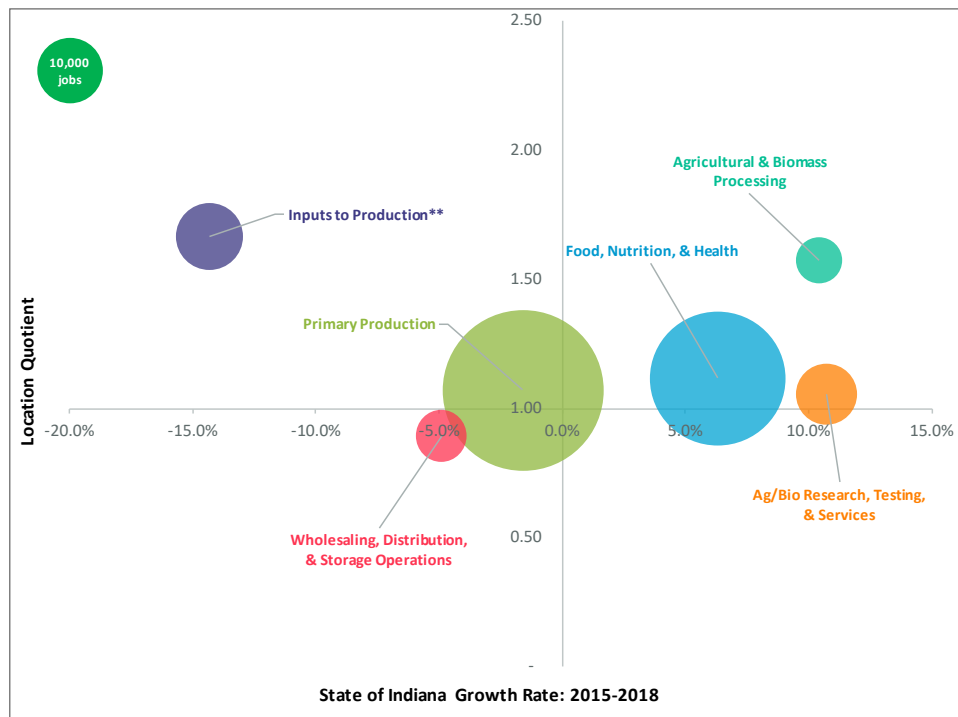
Figure 3 summarizes the 2015–2018 employment data. The Y-axis is the location quotient (LQ) in 2018, while the X-axis is the employment growth rate for 2015–2018. The size of each bubble is proportionate to its total 2018 employment. A comparatively strong performance is evident in the specialized sectors of Agricultural and Biomass Processing; Ag/Bio Research, Testing, and Services; and the large Food, Nutrition, and Health segment.

Only the Wholesaling, Distribution, and Storage Operations segment is nonconcentrated in Indiana (with an LQ <1). Of concern is the negative growth rate for the specialized Inputs to Production segment (although this may partly result from reclassification of Corteva in the NAICS).

⁵ The location quotient (LQ) metric measures the employment concentration within state or region to gauge the relative importance of an industry to that state or region. The location quotients measure the degree of job concentration relative to the national average. States or regions with an LQ greater than 1.0 are said to have a “concentration” in the industry. When the LQ is significantly above average, 1.20 or greater, the state or region is said to have a “specialization” in the industry.

Figure 3: Indiana Agbioscience Segment Performance (2015–2018)

(Bubble size is proportionate to employment volume)



Source: TEconomy analysis of BLS, CEW enhanced data from IMPLAN and Farm Proprietor employment data from the BEA.

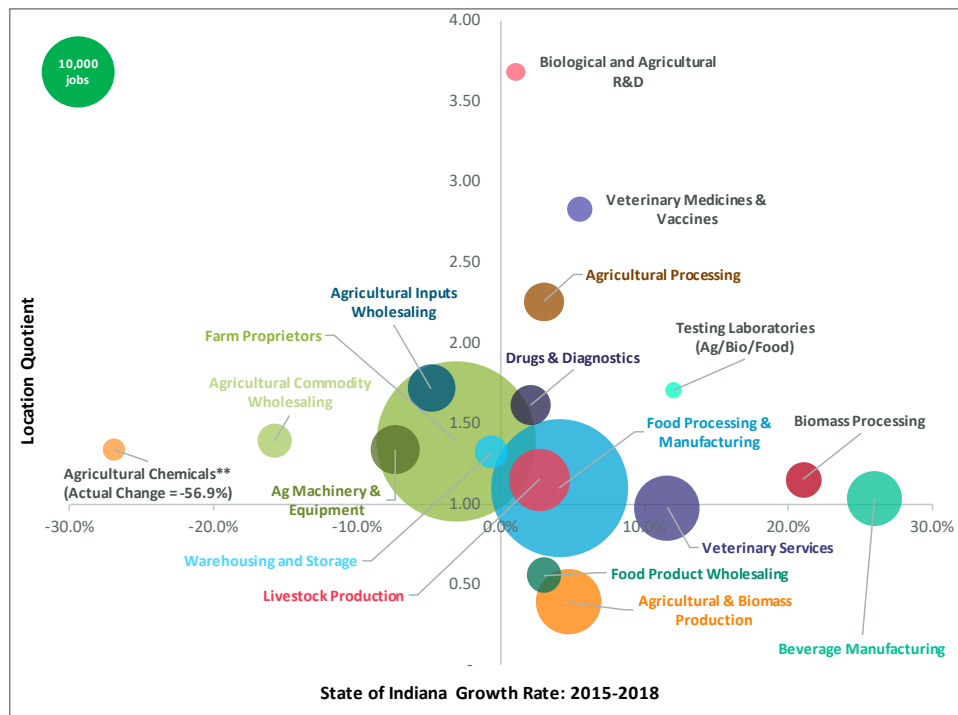
Figure 4 provides more detail by placing each of the subsectors of the agbioscience sector onto the LQ and growth quadrant graphic.

Several subsectors stand out as extremely specialized for Indiana (although relatively small in terms of absolute employment) and experiencing employment growth. These include Biological and Agricultural R&D, Veterinary Medicines and Vaccines, Agricultural Processing, Testing Laboratories, and Drugs and Diagnostics. Also, in the upper right quadrant (specialized and growing) is the large Food Processing and Manufacturing subsector, Beverage Manufacturing, Biomass Processing, and Livestock Production.

Up-and-coming subsectors (those that are growing but not yet specialized) are Veterinary Services, Food Product Wholesaling, and Agricultural and Biomass Production.

Figure 4: Indiana Agbioscience Subsector Performance (2015–2018)

(Bubble size is proportionate to employment volume)



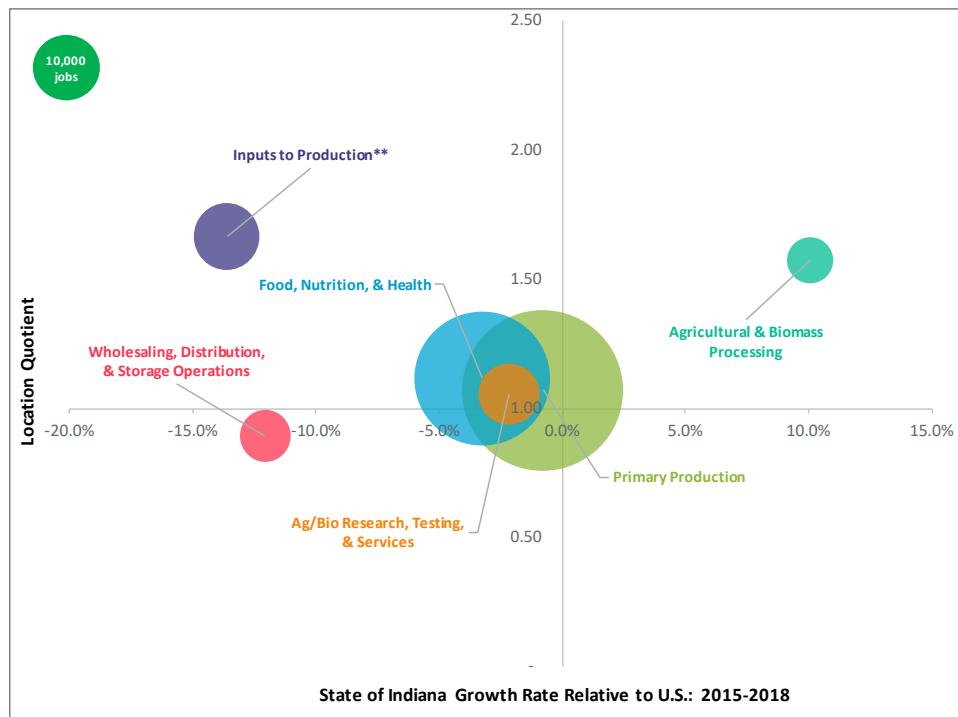
Source: TEconomy analysis of BLS, CEW enhanced data from IMPLAN and Farm Proprietor employment data from the BEA.

It can be seen that several specialized subsectors saw employment decline for 2015–2018. The largest of these in terms of employment is Farm Proprietors, although this follows a general national trend and is not atypical. Two specialized wholesaling subsectors, Agricultural Inputs Wholesaling and Agricultural Commodity Wholesaling, also experienced employment declines, as did Ag Machinery and Equipment.

While the previous figures (Figures 3 and 4) show that many Indiana agbioscience segments and subsectors have grown in absolute terms between 2015 and 2018, the situation is less positive when examining comparative growth versus the same segments and subsectors nationally. Figure 5 shows that, at the macro segment level, only Agricultural and Biomass Processing grew employment at a rate higher than the national employment growth rate. All of the other segments in Indiana lost ground.

Figure 5: Comparative Indiana Agbioscience Segment Performance (2015–2018)

(Bubble size is proportionate to employment volume)



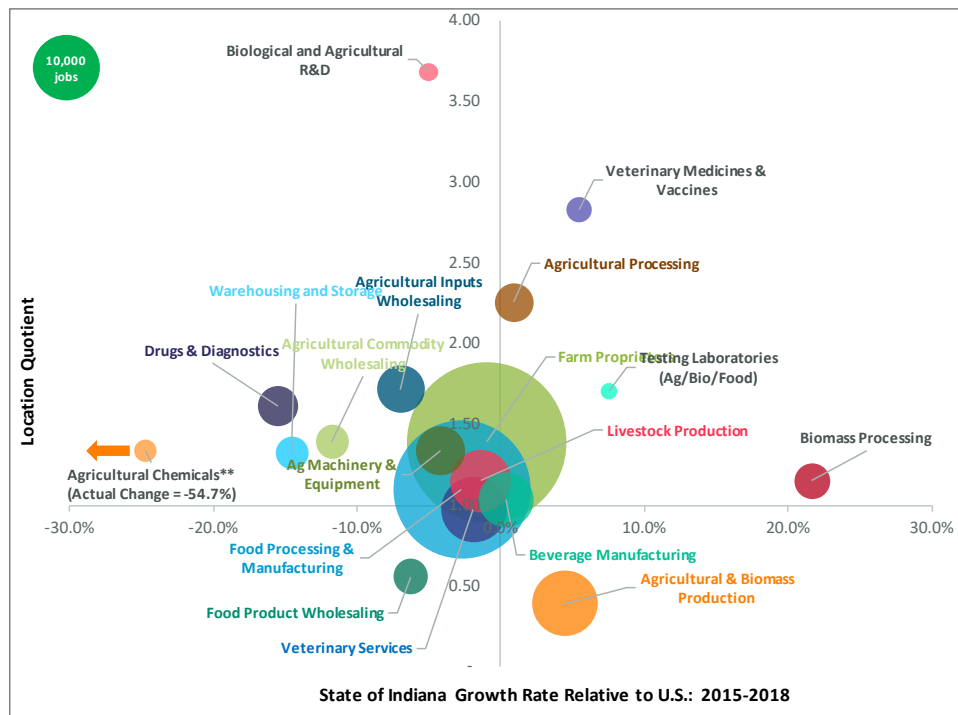
Source: TEconomy analysis of BLS, CEW enhanced data from IMPLAN and Farm Proprietor employment data from the BEA.

When examining the data at the more detailed subsector level (Figure 6), it is still evident that many of Indiana’s agbioscience sectors underperformed versus the overall gain or loss in the national average. Several subsectors did, however, outpace national growth, as follows:

- Veterinary Medicines and Vaccines
- Agricultural Processing
- Testing Laboratories (Ag/Bio/Food)
- Biomass Processing
- Beverage Manufacturing
- Agricultural and Biomass Production.

Figure 6: Comparative Indiana Agbioscience Subsector Performance (2015–2018)

(Bubble size is proportionate to employment volume)



Source: TEconomy analysis of BLS, CEW enhanced data from IMPLAN and Farm Proprietor employment data from the BEA.

The agbioscience cluster represents a relatively high-paying cluster in comparison with average private-sector wages in Indiana. **The average wage of \$51,825 in the total agbioscience cluster (not including farm proprietors) in 2018 is 8.27 percent higher than the average private-sector wage of \$47,864 in the state.** Several of the subsectors that compose the agbioscience cluster pay particularly strong average wages, with the highest as follows:

- Biological and Agricultural R&D—with 667 jobs and an average wage of \$178,747
- Veterinary Medicines and Vaccines—with 1,248 jobs and an average wage of \$122,866
- Drugs and Diagnostics—with 3,185 jobs and an average wage of \$114,903
- Agricultural Chemicals—with 1,022 jobs and an average wage of \$87,037
- Agricultural Processing—with 2,929 jobs and an average wage of \$76,035
- Agricultural Inputs Wholesaling—with 4,314 jobs and an average wage of \$60,934.

Wage levels below the average private-sector wage in Indiana are seen in Veterinary Services (\$35,156), Agricultural and Biomass Production (\$41,495), Livestock Production (\$38,590), Beverage Manufacturing (\$41,662), Food Processing and Manufacturing (\$47,146), and Warehousing and Storage (\$47,450).

Primary Agriculture Production in Indiana

While AgriNovus Indiana concentrates its work on “innovative agbiosciences,” most of the agbioscience segments and subsectors directly interface with the primary agricultural sector—either as inputs to it, or as processors or distributors of outputs from it. Indiana’s Primary Production sector may also serve as an important testbed for companies as they develop new products and services for agriculture. A large proportion of major innovative agbioscience companies are located in the Midwest of the United States because of the advantages provided by this region in terms of access to customers and an ability to develop products in a “relevant” environment. Indiana’s agricultural production sector, and its comparative strengths and concentrations, are thus part of the supportive ecosystem for further innovative agbioscience cluster development in the state.

The USDA’s National Agricultural Statistics Service (NASS) reports summary data on a state basis. Interestingly (and certainly counter to general national trends), the number of acres operated in farmland in Indiana increased for 2019 when compared with 2012. Data for 2019 show 14.9 million acres operated versus 14.7 million in 2012 (an increase of 1.36 percent). The number of farming operations, however, declined (from 60,000 in 2012 to 56,000 in 2019). As a result, the average size of operations increased, rising from 245 acres in 2012 to 266 acres in 2019 (an 8.57 percent increase in the average number of acres operated on Indiana farms). This trend of fewer but larger farms reflects a trend seen nationwide; although there is potential for this trend to reverse as opportunities in local food, specialty crops, organic production, etc., provide new outlets for smaller farm operations to expand their markets.

In terms of overall financial output (as measured by total farm receipts), it is evident that the state has experienced a declining trend in output (both in nominal dollars and in real 2020 dollars) from 2012 through 2018. Table 2 and Figure 7 illustrate this with the annual data (as reported by USDA NASS)⁶ and fitted linear trend line.

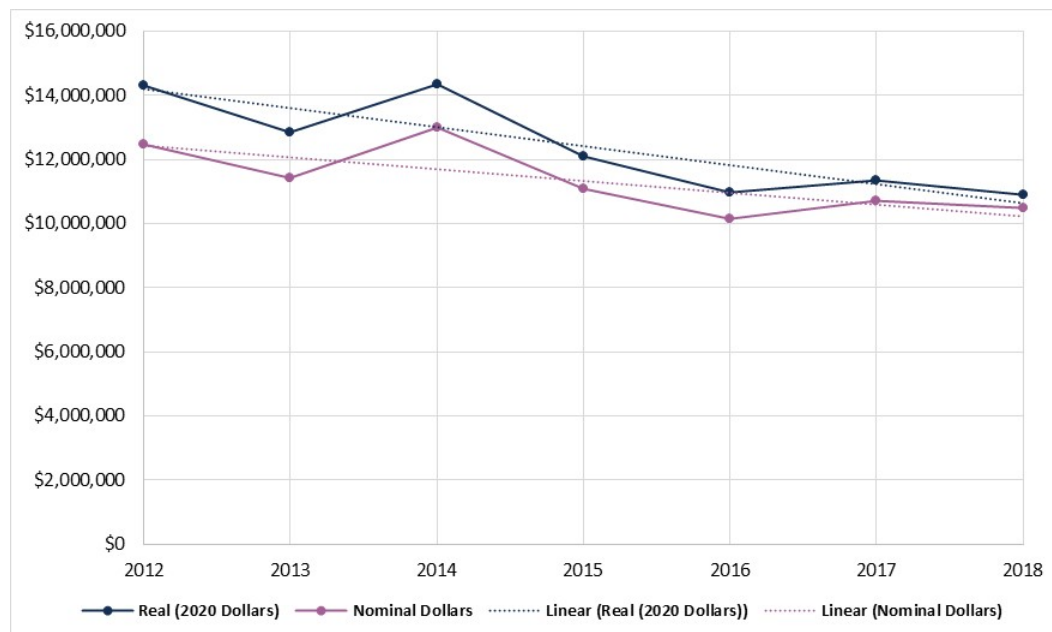
Table 2: Indiana Agriculture Cash Receipts for All Commodities (2012–2018, \$000s)

Year	Real (2020 Dollars)	Nominal Dollars	Percent of U.S.
2012	\$14,295,371	\$12,488,722	3.1
2013	\$12,864,161	\$11,437,654	2.8
2014	\$14,354,332	\$12,997,560	3.1
2015	\$12,106,172	\$11,071,942	2.9
2016	\$10,973,339	\$10,139,694	2.8
2017	\$11,355,920	\$10,694,097	2.9
2018	\$10,889,390	\$10,500,857	2.8

Source: USDA NASS.

⁶ Source: USDA NASS. “Farm income and wealth statistics.” “Cash receipts by commodity, state ranking, 2019.” <https://data.ers.usda.gov/reports.aspx?ID=17844>.

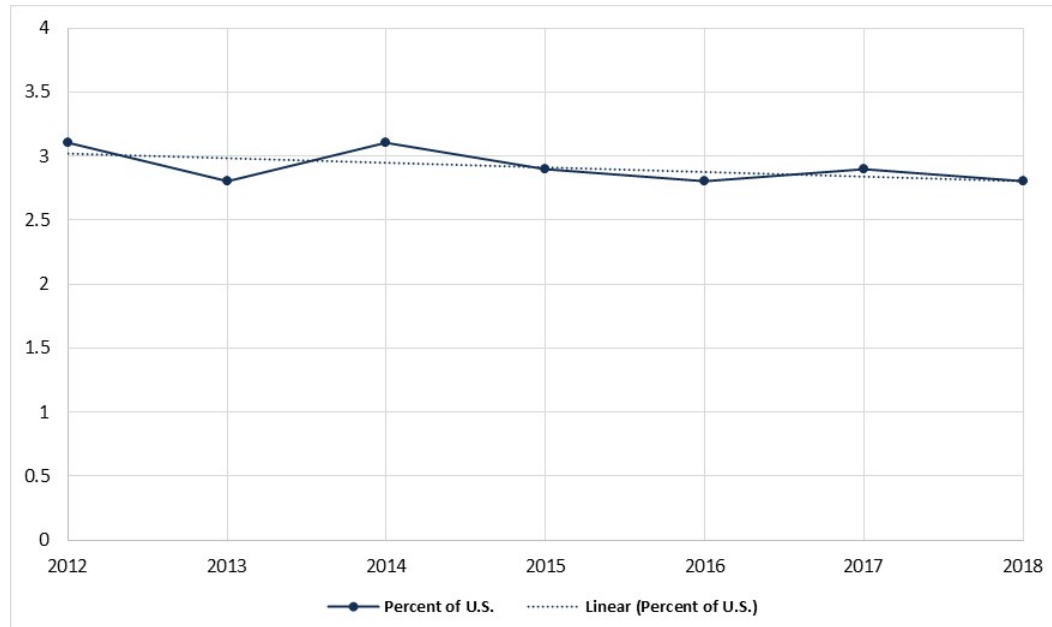
Figure 7: Indiana Agriculture Cash Receipts for All Commodities (2012–2018, \$000s)



Source: USDA NASS.

The decline in Indiana farm dollar output reflects a real decline versus the United States overall, with Indiana trending downward in terms of percent of all U.S. cash receipts comprising Indiana (Figure 8).

Figure 8: Indiana Agriculture Cash Receipts as a Percent of U.S. Cash Receipts for All Commodities (2012–2018)



Source: TEconomy analysis of USDA NASS data.

Indiana's agriculture is only moderately diverse in terms of the crops it produces. The largest crops, by far, are corn and soybeans. For 2019, corn was harvested on 4.82 million acres of Indiana farmland with a total production value of \$3.34 billion. Soybeans were harvested on 5.36 million acres with a

production value of \$2.49 billion. Other major crops in Indiana include hay (\$230.1 million), wheat (\$79.8 million), melons (\$35.3 million), pumpkins (\$16.9 million), and mint (\$6.8 million).

Livestock and poultry production are also significant contributors. The Indiana State Department of Agriculture notes that livestock production generated the following sales for 2017:

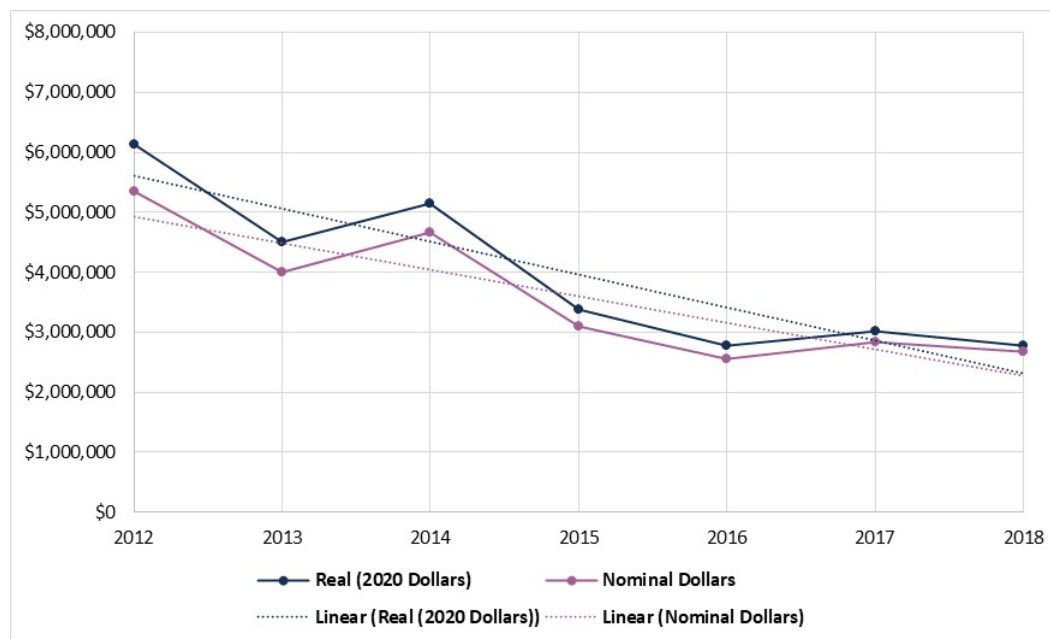
- Meat animals: \$1.62 billion (primarily pork and beef)
- Poultry and eggs: \$1.18 billion
- Dairy: \$750 million.

In the 2015 report, it was noted as follows:

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.

Unfortunately, this trend no longer holds true, reversing for 2012 through 2018, with net cash income shifting onto a declining trajectory. Figure 9 shows the decline experienced over this time period in net cash income for farms in Indiana.

Figure 9: Indiana Farms Net Cash Income (2012–2018, \$000s)



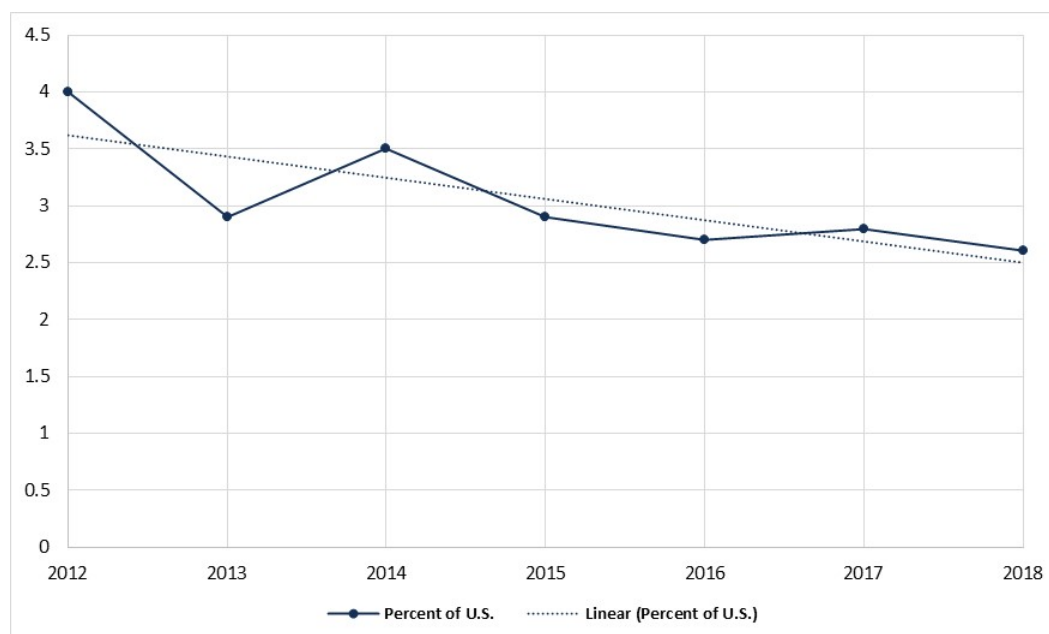
Source: TEconomy analysis of USDA NASS data.

This steep trajectory shows that, in terms of real (2020) dollars, net cash income for farms in Indiana has basically halved over the 2012–2018 time frame.

The decline in Indiana farms net cash income reflects a real decline versus the U.S. overall, with Indiana trending downward in comparison with the U.S. total statistic. Figure 10 shows Indiana farms net cash income as a percentage of all U.S. farms net cash income, and Indiana demonstrates a downward

trajectory. With farming being an important component of rural and small-town economies across Indiana, the recent financial performance of the primary agriculture sector should be a matter of concern for the state and economic developers.

Figure 10: Indiana Farms Net Cash Income as a Percent of All U.S. Farms Net Cash Income (2012–2018)



Source: TEconomy analysis of USDA NASS data.

Summary

The agbioscience industry continues to be an important advanced industry for Indiana. Inclusive of agricultural production, the agbioscience cluster directly employed 142,358 personnel in the state in 2018. The non-Primary Production component of the agbioscience cluster (activities outside of on-farm direct agricultural production) experienced a moderate employment growth rate between 2015 and 2018 of 2.7 percent (reaching a total of 93,174 jobs in 2018). Overall, the agbiosciences have not kept pace with average private-sector job gains in Indiana (which were 4.2 percent between 2015 and 2018). The average wage of \$51,825 in the total agbioscience cluster in 2018 is, however, 8.27 percent higher than the average private-sector wage of \$47,864 in the state.

In looking at the individual segments and subsectors that compose the agbiosciences, Indiana is specialized in many of them (having an LQ > 1.2). In the few where it is not specialized, Indiana still sustained job growth (except in the Wholesaling, Distribution, and Storage Operations segment). Best performing for Indiana in terms of being specialized and growing in employment between 2015 and 2018 are Biological and Agricultural R&D, Veterinary Medicines and Vaccines, Agricultural Processing, Testing Laboratories, and Drugs and Diagnostics. Other specialized and growing subsectors include the large Food Processing and Manufacturing subsector, Beverage Manufacturing, Biomass Processing, and Livestock Production. Emerging subsectors (those that are growing but not yet specialized) are Veterinary Services, Food Product Wholesaling, and Agricultural and Biomass Production.

Of concern is the observation that, at the macro segment level, only Agricultural and Biomass Processing grew employment in Indiana at a rate higher than the national employment growth rate. All of the other

segments in Indiana lost ground (thus representing a comparative decline in national market share). At a subsector level, out of 18 subsectors tracked, only 6 exceeded the average national employment growth rate for 2015–2018:

- Veterinary Medicines and Vaccines
- Agricultural Processing
- Testing Laboratories (Ag/Bio/Food)
- Biomass Processing
- Beverage Manufacturing
- Agricultural and Biomass Production.

While Primary Production may be declining in terms of employment and direct output generation in Indiana, it continues to be an extremely important economic driver for Indiana (especially rural and small-town Indiana), accounting for more than \$10.5 billion in sales in 2018. The full economic impacts of the agbiosciences and Primary Production in Indiana are explored further in Chapter V.

Chapter III. 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 more than 99 percent of university-based agbioscience research performed in Indiana.

In 2012, National Science Foundation (NSF) higher education R&D expenditure data showed Indiana having \$118 million in academic agricultural sciences R&D expenditures. This increased to \$120 million in 2015, and continued to grow, reaching \$127.9 million in 2018. Since 2012, Indiana has seen academic agricultural sciences R&D grow 8.4 percent.

Insights into strength areas in Indiana academic agbioscience R&D may be derived from analysis of publications produced in agricultural and associated academic disciplines/fields. As with the 2015 analysis, TEconomy considers three macro categories of academic fields in examining publications for Indiana institutions:

- **Principal Agriculture and Agbioscience Fields**—comprising disciplines that are typically housed in departments or programs under a college of agriculture within a university (or within veterinary medicine).
- **Related Basic Research Fields**—comprising basic science research fields (primarily, but not exclusively, in the life sciences) that are likely to be conducting research of relevance to agbioscience advancement or application.
- **Ancillary or Related Application Fields**—largely comprising applied fields that may have some content related to agbioscience or related environmental science areas.

Table 3 summarizes data for the individual academic fields under each of the three categories. Data are for publications in the 2015 through 2019 time frame showing the number of combined records by field for all Indiana institutions, the percent of analyzed publications that fall within each field, and a publication quotient (which, akin to a location quotient or LQ, measures the specialization of Indiana in a field where 1.0 equals parity with the nation in the discipline, and a number higher than 1.0 indicates a comparative specialization). Publications quotients (PQs) above 1.1 are highlighted, indicative of Indiana being at least 10 percent more specialized in a field than the nation. Comparative PQs are shown for the 2009–2014 time frame in each field to assess movement in PQs over time. In each macro category, fields are sorted by the number of publications.

Table 3: Agbioscience and Associated/Ancillary Academic Research Fields—Indiana Publications for 2015–2019.

Publication Quotient (PQ) Comparison Shown for 2009–2014 and 2015–2019

Field	Web of Science Categories	Indiana Number of Records 2015–2019	Percent of All Assessed IN Publications in this Field ⁷	Total U.S. Records 2015–2019	2009–2014 PQ	2015–2019 PQ
Principal Agriculture and Agbioscience Fields	Plant Sciences	846	7.00	25,264	1.28	1.12
	Food Science Technology	670	5.54	18,697	0.95	1.20
	Veterinary Sciences	607	5.02	18,075	1.17	1.13
	Agronomy	439	3.63	10,754	1.27	1.37
	Agriculture Dairy Animal Science	423	3.50	7,708	1.88	1.84
	Entomology	300	2.48	9,830	1.12	1.02
	Forestry	216	1.79	6,894	1.22	1.05
	Soil Science	175	1.45	5,148	1.15	1.14
	Horticulture	151	1.25	4,769	0.94	1.06
	Agriculture Multidisciplinary	145	1.20	4,386	1.18	1.11
	Agricultural Economics Policy	139	1.15	2,170	2.02	2.15
	Agricultural Engineering	97	0.80	3,291	1.10	0.99
Related Basic Research Fields	Biochemistry Molecular Biology	2,065	17.06	82,220	0.88	0.84
	Cell Biology	1,176	9.72	55,530	0.71	0.71
	Ecology	1,136	9.39	38,387	1.07	0.99
	Genetics Heredity	1,111	9.18	39,059	0.99	0.95
	Microbiology	776	6.41	33,849	0.70	0.77
	Biotechnology Applied Microbiology	775	6.40	29,220	0.92	0.89
	Immunology	747	6.17	44,161	0.48	0.57
	Chemistry Organic	673	5.56	13,564	1.35	1.66
	Biology	508	4.20	21,347	0.95	0.80
	Evolutionary Biology	483	3.99	13,817	1.26	1.17
	Biophysics	429	3.55	17,330	0.99	0.83
	Zoology	412	3.40	17,531	0.94	0.79
	Virology	249	2.06	13,103	0.52	0.64
	Parasitology	236	1.95	8,574	0.79	0.92
Ancillary or Related Application Fields	Infectious Diseases	366	3.02	18,659	0.56	0.66
	Environmental Sciences	299	2.47	11,867	0.84	0.85
	Chemistry Applied	296	2.45	5,492	1.28	1.81
	Water Resources	98	0.81	2,451	0.97	1.34
	Nutrition Dietetics	87	0.72	3,076	0.83	0.95
	Environmental Studies	76	0.63	2,224	1.14	1.15
	Limnology	68	0.56	1,232	1.71	1.85
	Energy Fuels	59	0.49	2,016	0.79	0.98
	Engineering Chemical	48	0.40	1,120	0.91	1.44
	Materials Science Biomaterials	35	0.29	1,667	0.63	0.70
	Green Sustainable Science Technology	34	0.281	651	1.88	1.75
	Multidisciplinary Sciences	26	0.215	925	0.61	0.94
	Meteorology Atmospheric Sciences	25	0.207	706	1.97	1.19
	Mycology	25	0.207	919	0.54	0.91
	Engineering Environmental	15	0.124	689	0.86	0.73
	Materials Science Paper Wood	6	0.05	418	0.77	0.48
	Remote Sensing	3	0.025	187	0.92	0.54

Source: TEconomy analysis of Web of Science data.

⁷ Column does not sum to 100 percent because an individual paper may be classified in more than one field.

In the first category of Principal Agriculture and Agbioscience Fields, Indiana generated 4,208 publications with the top fields being Plant Sciences (846), Food Science Technology (670), and Veterinary Sciences (607). It should be noted that publications in academic journals are not the exclusive domain of academic scientists. Indeed, companies in Indiana, such as Corteva, demonstrate publishing activity also.

As noted above, the “publications quotient” shown in Table 3 provides a measure of whether the volume of publishing in the field is higher or lower in Indiana than would be expected given national normative levels of publishing in that same field. 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 1.1 or higher is highlighted indicating a comparative specialization in that discipline in Indiana (with activity equal to or greater than 10 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 the following:

- **Plant Sciences**, 846 publications (PQ ≤ 1.12)
- **Food Science Technology**, 670 publications (1.20)—This field moved from being unspecialized in 2009–2014 (PQ of 0.95).
- **Veterinary Sciences**, 607 publications (1.13)
- **Agronomy**, 439 publications (1.37)
- **Agriculture Dairy Animal Science**, 423 publications (1.84)
- **Soil Science**, 175 publications (1.14)
- **Agriculture Multidisciplinary**, 145 publications (1.11)
- **Agricultural Economics Policy**, 139 publications (2.15).

Of particular note in the Principal Agriculture and Agbioscience Fields macro category is the fact that Indiana is higher or somewhat higher in its PQ in all fields except for Agricultural Engineering (and even in that, Indiana is basically at parity with the nation with a PQ of 0.99).

In the Related Basic Research Fields of life sciences, Indiana has below average concentration in all of the listed disciplines except two—**Organic Chemistry** (673 publications and a PQ of 1.66) and **Evolutionary Biology** (483 publications and a PQ of 1.17).

In the more peripherally related Ancillary or Related Application Fields category, specializations for Indiana are evident in the following:

- Fields associated with **chemistry**. Including Chemistry Applied (296 publications and 1.81 PQ) and “Engineering Chemical” (48 publications and a 1.44 PQ).
- Fields associated with **water**. Including Water Resources (98 publications, PQ = 1.34) and Limnology (68 publications, PQ = 1.85).

- Fields associated with **the environment and sustainability**. Including Environmental Studies (76 publications, PQ = 1.15), Green Sustainable Science Technology (34 publications, PQ = 1.75), and Meteorology Atmospheric Sciences (25 publications, PQ = 1.19).

Field areas where a comparative weakness is observable in Indiana (as measured in having a relatively low PQ) seem to relate to infectious diseases and associated pathogen biology, where Indiana has relatively low PQs in Microbiology (PQ = 0.77), Immunology (0.57), Virology (0.64), Parasitology (0.92), Infectious Diseases (0.66), and Mycology (0.91).

OmniViz™ Analysis of Indiana Agbioscience Publications

In the 2015 analysis, Battelle used 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 allows for 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. The 2015 report comprises OmniViz™ analysis for a dataset of publications covering the time period of 2009 through June 2014. TEconomy has deployed a matching OmniViz™ analysis for 2015–2019 publications.

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 TEconomy:** The identification of key themes and groupings that result from OmniViz™ requires analytical expertise to review, interpret, and explain the types of technologies and specific activities that are represented in the cluster.

OmniViz™ output is provided in both graphical and spreadsheet table formats. This allows for visualization of key cluster areas and deeper investigation of the individual publications contained within each cluster.

The analysis identified 44 clusters of agbioscience research publishing activity by Indiana-based authors (primarily, but not exclusively, Purdue University researchers). The clusters range in size from a high of 420 papers in Soils, Soil Nutrients and Water to several small clusters with less than 10 records (Table 4).

Table 4: Cluster Analysis Findings—Themes, Associated Clusters, and Publication Counts (2015–2019)

Theme	Cluster Name	Number of Publications
Veterinary Medicine	Canine Veterinary Medicine	170
	Viral Infectious Diseases	54
	Equine Veterinary Medicine	39
	Feline Veterinary Medicine	39
	Miscellaneous Veterinary Research	27
	Veterinary Medicine Immunology/Serology	17
	Poultry Health & Veterinary Medicine	14
Animal Science, Livestock & Nutrition	Broiler Nutrition	159
	Dairy Cattle	123
	Swine Nutrition, Housing & Performance	73
Plant Science & Plant Improvement	Soybeans	289
	Corn & Grain	170
	Markers, Genetics & Breeding	146
	Stress Tolerance & Wheat	114
	Grain Storage	56
	Plant Metabolism. Biosynthesis, Fatty Acids & Oils	51
	Plant Genetics & Traits	49
	Greenhouse Tomatoes	37
	Flowers, Leaves & Markers	22
	Markers & Transgenics	19
	Rice Transgenics	18
Crop Protection	Insecticides – Insects/Pests	92
	Herbicides, Weeds & Soybeans	38
	Insecticides - Chemicals	21
Food Science	Carbohydrate Chemistry & Food	60
	Meat Science	41
	Starch/Carbohydrate Chemistry	23
	Fractionation & Extraction	14
Economics & Markets	Agricultural Economics, Markets	47
	Agricultural Economics. Prices & Markets	12
Water, Soils & Environment	Soils. Water/Nutrients/Nitrogen	420
	Water	239
	Precipitation, Drought & Climate Change	36
	Climate Change Impact on Food & Environment	17
	Watersheds & Water Quality	6
Individual Clusters	Forestry & Forest Ecology	236
	Bacteria & Bacterial Pathogens	90
	Sensors & Detection Technology	30
	Farm Management	24
	Imaging/Microscopy	21
	Evolutionary & Developmental Biology	20
	Vector Immunology. Gene Modulation	14
	Spatial Analysis	13
	Invasive Plants	10
		Count = 3,210

Source: TEconomy OmniViz™ cluster analysis of Web of Science data.

Table 5 ranks the major thematic clusters evident in Indiana’s research publications by total number of publications.

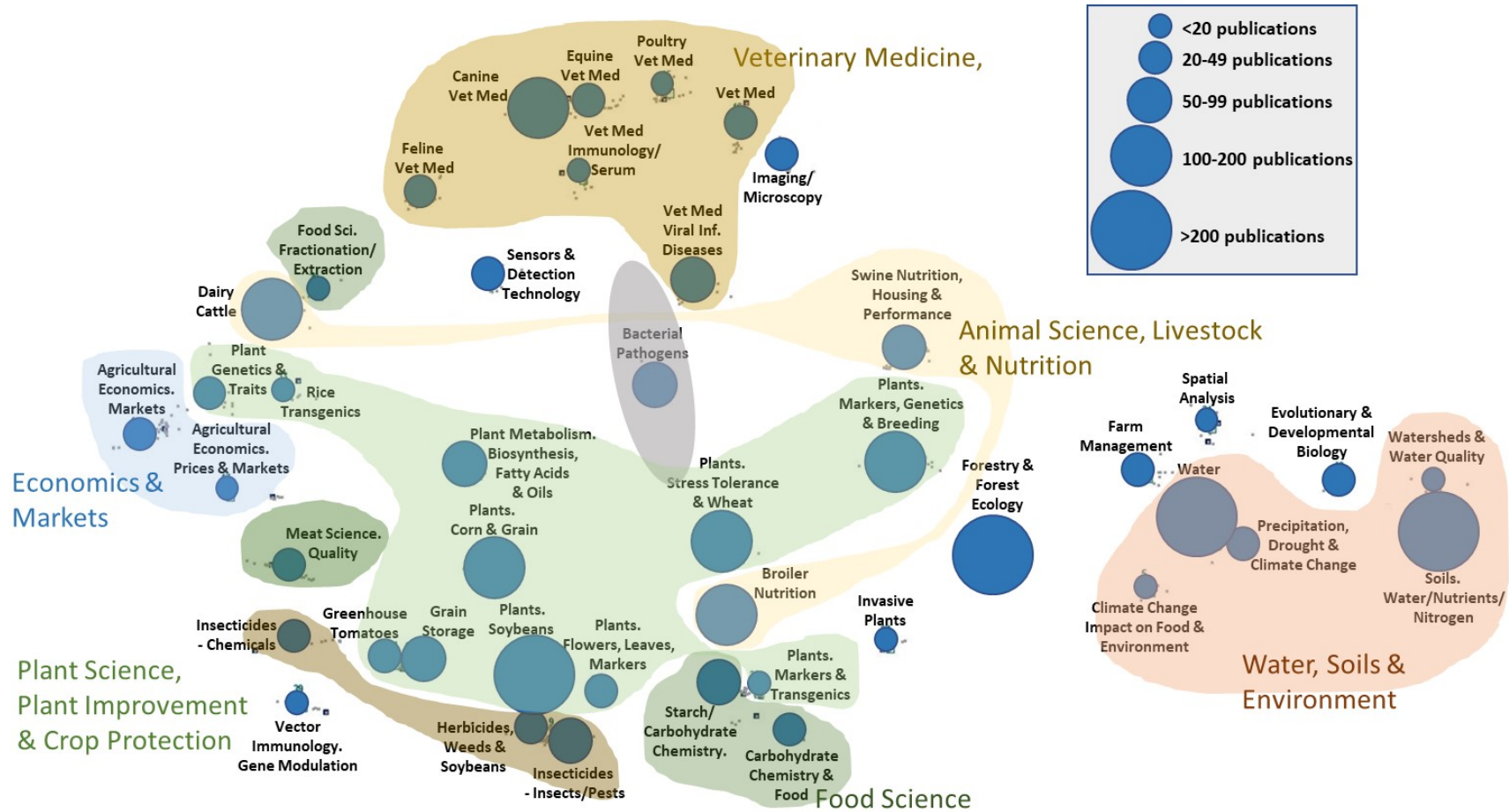
Table 5: Major Themes in the Cluster Analysis

Meta Cluster (Theme)	Number of Publications	Percent of Publications
Plant Science & Plant Improvement	971	30.2%
Water, Soils & Environment	718	22.4%
Veterinary Medicine	360	11.2%
Animal Science, Livestock & Nutrition	355	11.1%
Forestry & Forest Ecology	236	7.4%
Crop Protection	151	4.7%
Food Science	138	4.3%
Bacteria & Bacterial Pathogens (mixed)	90	2.8%
Economics & Markets	59	1.8%
Sensors & Detection Technology	30	0.9%

Source: TEconomy OmniViz™ cluster analysis of Web of Science data.

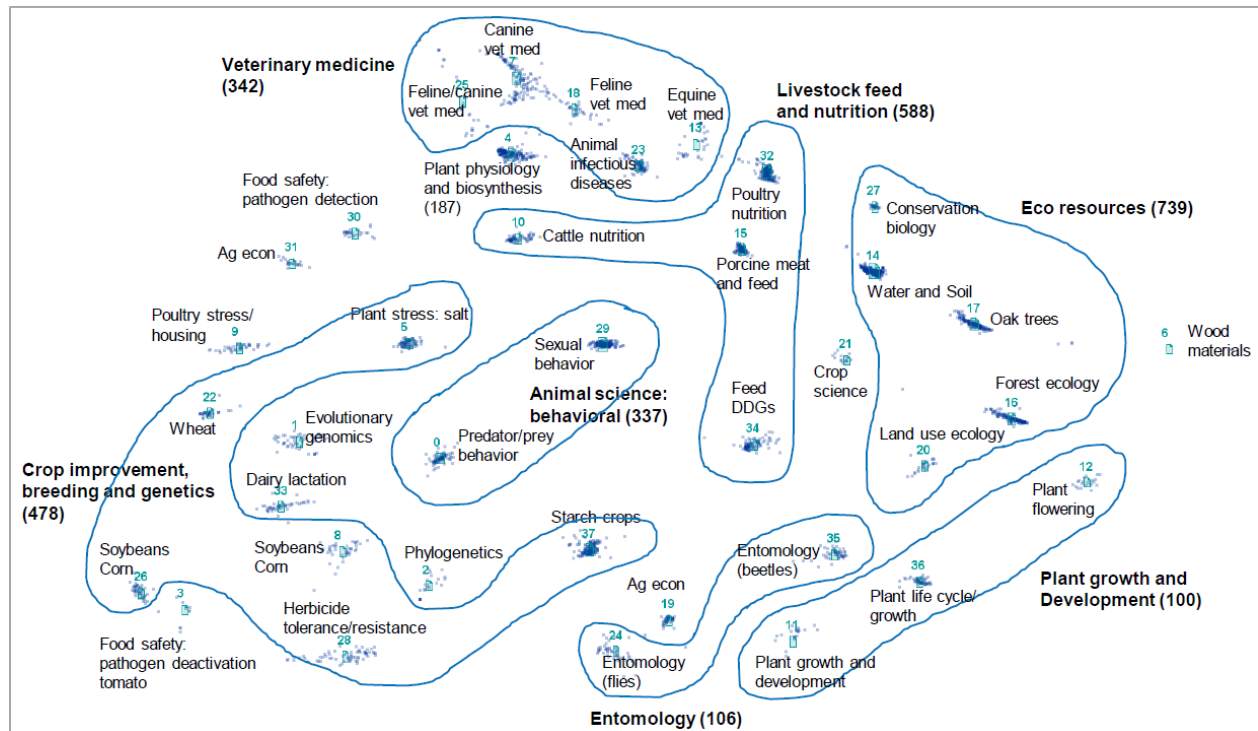
Figure 11 provides another perspective, using a visualization graphic to show each of the clusters and their thematic grouping by TEconomy.

Figure 11: Cluster Map. Themes, Associated Clusters, and Publication Counts (2015–2019)



Source: TEconomy OmniViz™ cluster analysis of Web of Science data

The current cluster analysis can be compared with the original analysis contained in the 2015 Battelle report (Figure 12).



Source: Battelle OmniViz™ cluster analysis of Web of Science data.

Perhaps not surprisingly, since faculty will typically advance their existing research further and build upon existing research interests, there are many areas of similarity between the cluster analysis findings in the 2015 study and in the present study. There are, however, some significant differences evident; and Table 6 summarizes the similarities and differences.

Table 6: 2015 Cluster Status in the 2020 Cluster Analysis

Previous Cluster Analysis (2015 Battelle Report)	Current Cluster Analysis (2020 TEconomy Report)
Veterinary medicine, with companion animal emphasis	Similar finding. Infectious disease presence.
Livestock nutrition/feed products	Similar finding. Especially in swine and broilers.
Crop improvement in bulk commodity crops (soybeans, corn, and wheat)	Similar finding for soybean, corn, and wheat. Also rice.
Basic work in plant physiology, growth, and development	Similar finding. Robust presence of genetics and genomics (traits and markers).
Behavioral animal sciences	Not found in similar stand-alone cluster. More integrated into other research cluster areas.
Research in soils, water, forests, and ecological resources	Similar finding.
Niche areas in entomology (especially flies and beetles), tomatoes, food safety, stress tolerance	Entomology clusters not evident. But crop protection, more generally, is a major cluster.
A significant crosscutting genomics presence	Similar finding.

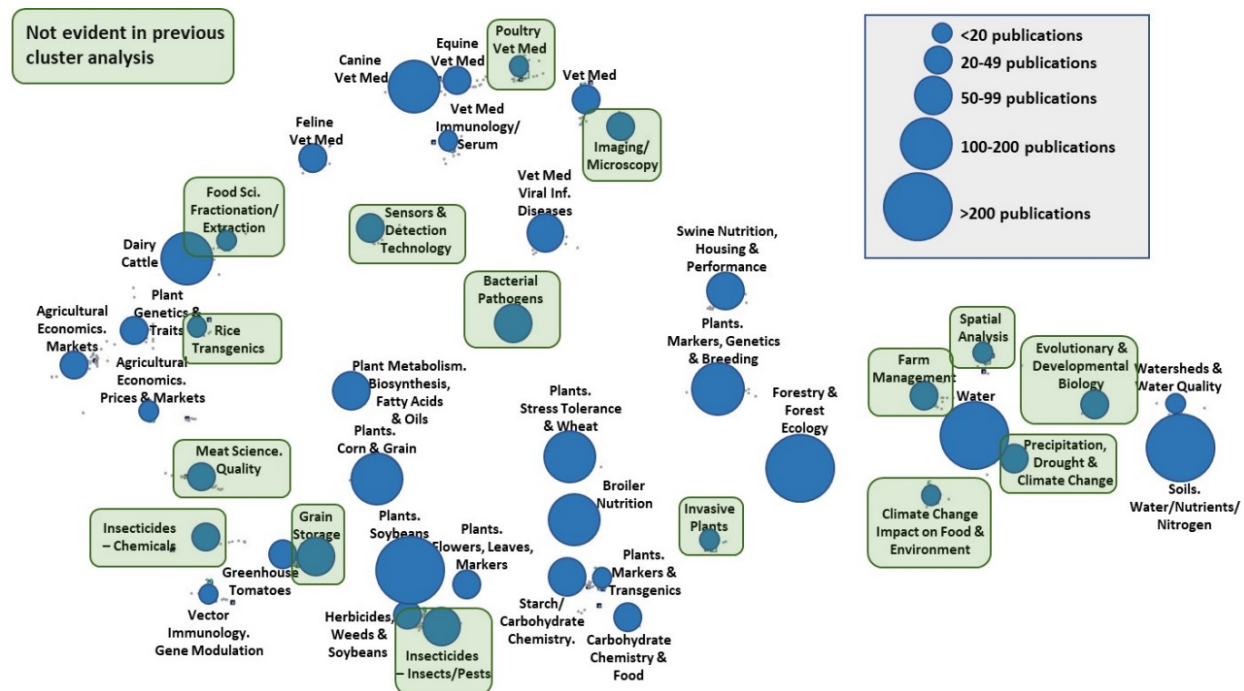
Source: TEConomy analysis.

Several new or increased emphasis clusters are now evident:

- An increased cluster emphasis in agricultural **economics and markets**
- **Food science cluster** (starch was evident before, but at lower levels)
- New **sensors and detection technology** cluster
- Research on climate change impacts on agriculture.

Figure 13 provides more detail, highlighting each individual cluster that is newly evident in the latest cluster analysis of Indiana publications.

Figure 13: Individual Clusters Newly Evident in the 2020 Analysis

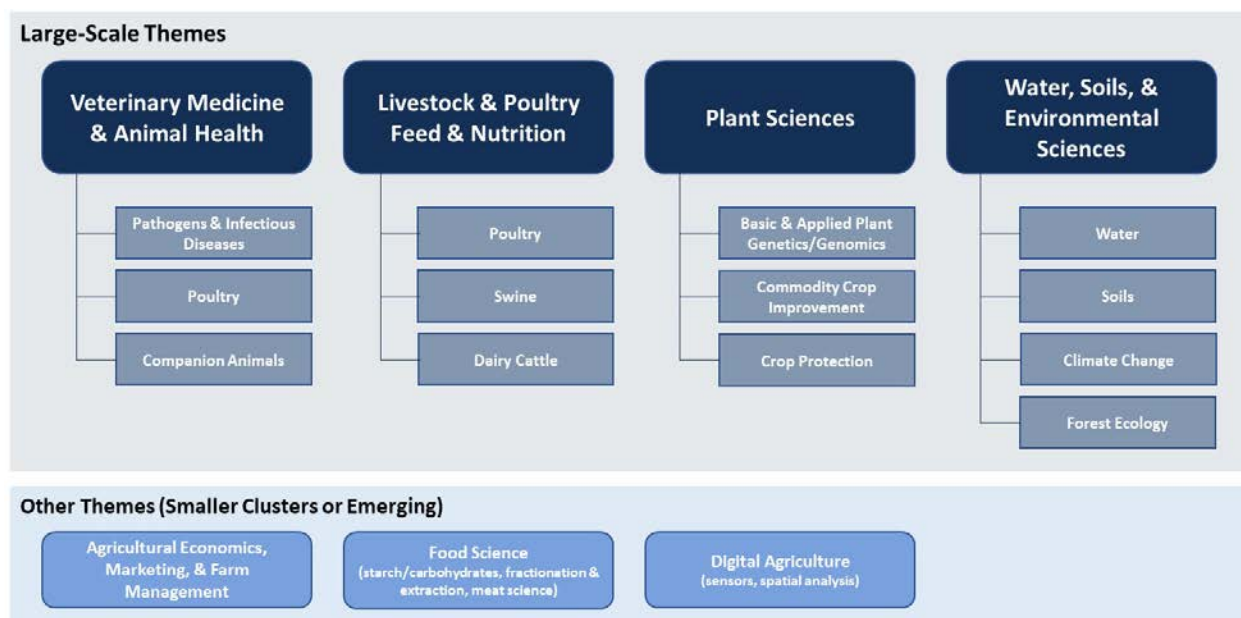


Source: TEconomy OmniViz™ cluster analysis of Web of Science data.

Conclusions from the Publications Analysis

Overall, the assessment of published research activity in the agbiosciences and associated disciplines in Indiana indicate key thematic strengths to be in the areas summarized in Figure 14. The four large-scale themes are the same, or similar, to those identified in the 2015 analysis—with some changes or additions in the more focused areas of work under these themes. There are also three smaller themes that are evident in Indiana’s publishing.

Figure 14. Primary Agbioscience and Related-Field Strength Areas in Indiana Research Publishing



Source: TEconomy Partners, LLC.

Agbioscience Patent Generation in Indiana

In addition to basic and applied research in the agbiosciences, patent data are an important measure of agbioscience innovation activity.

One common indicator used to assess a state’s innovation activity in specific technology areas is the extent of patenting generated by local inventors or assigned to local industry firms. Examination of in-state inventor patenting activity can point to areas of technology or market application specializations where Indiana has a competitive advantage in agbioscience innovation. Similarly, examination of the agbioscience patent holdings assigned to Indiana companies can yield insights on the current industry environment and market areas where companies are advancing innovative products and services.

To evaluate this indicator of innovation activity within Indiana, TEconomy analyzed patent awards generated for Indiana inventors over the 2015–2019 time period using U.S. Patent and Trademark Office (USPTO) patent record data. Only patent awards associated with Indiana inventors were used since they are a more accurate measure of innovation that is generated within the state rather than intellectual property (IP) that companies “import” as assignees from other states or regions. There were 1,553 total agbioscience patent awards generated in Indiana between 2015–2019, with an average of 310 patent awards generated per full calendar year.

Table 7 shows the leading detailed technology class areas present across the agbioscience patents generated in Indiana. Novel Plant Types comprise the largest category of patents generated within the state, indicating a strong focus on innovative activity in this space. Several other leading areas include Fertilizers and Agricultural Chemicals and Genetic Engineering, Microorganisms, or Enzymes. Levels of patenting across the five years analyzed have remained relatively steady.

Table 7: Indiana Agbioscience Patents (2015–2019)

Ag/bio Patent Group (w/5+ Patents)	2015	2016	2017	2018	2019	Total, 2015-2019
Novel Plant Types	111	102	89	91	75	468
Fertilizers and Agricultural Chemicals	74	53	53	34	41	255
Genetic Engineering, Microorganisms, or Enzymes	23	36	50	54	56	219
Agricultural Machinery and Planting Processes	12	13	21	26	28	100
Animal Husbandry and Management	20	20	17	12	15	84
Food Production and Additives	22	13	9	11	17	72
Fermented Beverages	2	1		1	2	6
Milling Processes	1	2	1		1	5
Veterinary Instruments and Tools	1	1		2	1	5
All Other Agbio	82	85	81	46	45	339
Total, Indiana Ag/bio-related Patents	348	326	321	277	281	1,553

Source: TEconomy analysis of USPTO data.

Table 8 shows that Corteva is by far the largest generator of patented innovations in Indiana agbioscience. Monsanto (since acquired by Bayer) also holds multiple Indiana-inventor patent assignments.

Table 8: Indiana Agbioscience Patents by Indiana Inventor (2015–2019)

Assignee of Patent w/Indiana Inventor (3+ Patents)	Number of Patents
CORTEVA AGRISCIENCE (including predecessors)	842
MONSANTO TECHNOLOGY LLC	190
MEAD JOHNSON NUTRITION CO	36
MID-WEST METAL PRODUCTS CO INC	30
PURDUE RESEARCH FOUNDATION	28
CNH INDUSTRIAL AMERICA LLC	19
CTB INC	18
UNIVERSITY OF INDIANA RESEARCH & TECHNOLOGY CORP	15
ABI ATTACHMENTS INC	11
ROSE ACRE FARMS INC	10
SYNGENTA PARTICIPATIONS AG	10
ELANCO US INC	9
LIMAGRAIN	7
FORMAX INC	6
HYDRO-GEAR LP	6
FAIRLIFE LLC	5
KINZE MANUFACTURING INC	4
TRIBINE INDUSTRIES LLC	4
HILL'S PET NUTRITION INC	4
JBS UNITED INC	3
LYONS INDUSTRIES INC	3
SEPRO CORP	3
Total, Indiana Ag/bio-related Patents	1,553

Source: TEconomy analysis of USPTO data.

Patents routinely cite prior art patents as references in documenting the new IP they create, and the referenced patents usually contain fundamental ideas/concepts used in developing the new IP protected by subsequent patents. The original patent is thus said to generate forward citations for all patents that reference its IP, and the extent to which a patent generates forward citations can be used as proxy for its value in creating “forward innovation” beyond its current value. Critical IP that fundamentally advances the state of technology or science in an area will likely be cited by many other patents in further advancing the area (or new areas). Areas of differentiated innovation for a state will ideally have both a high specialization in specific technology areas, as demonstrated through signature technology areas found in patenting activity, as well as generating high amounts of forward innovation activity in those areas.

As an additional perspective in examining trends in patenting, Figure 15 uses the concepts of specialization and forward innovation to show the profiles of key Indiana agbioscience technology areas in IP generation activity relative to national trends. A specialization index shows how specialized the patent technology class is in Indiana relative to proportions of U.S. patenting in that area (>1 indicates more specialized relative to U.S., <1 indicates less specialized). Similarly, a forward citation index shows volume of forward citations for Indiana patents relative to proportions of forward citations generated in class areas across all U.S. patents (>1 indicates more forward citations than expected given U.S. trends, <1 indicates fewer forward citations than expected given U.S. trends). The size of the data points shows the quantity of patents in specific technology class areas, while the coloring of the data points shows their association with an aggregate technology category, such as agriculture or manufacturing.

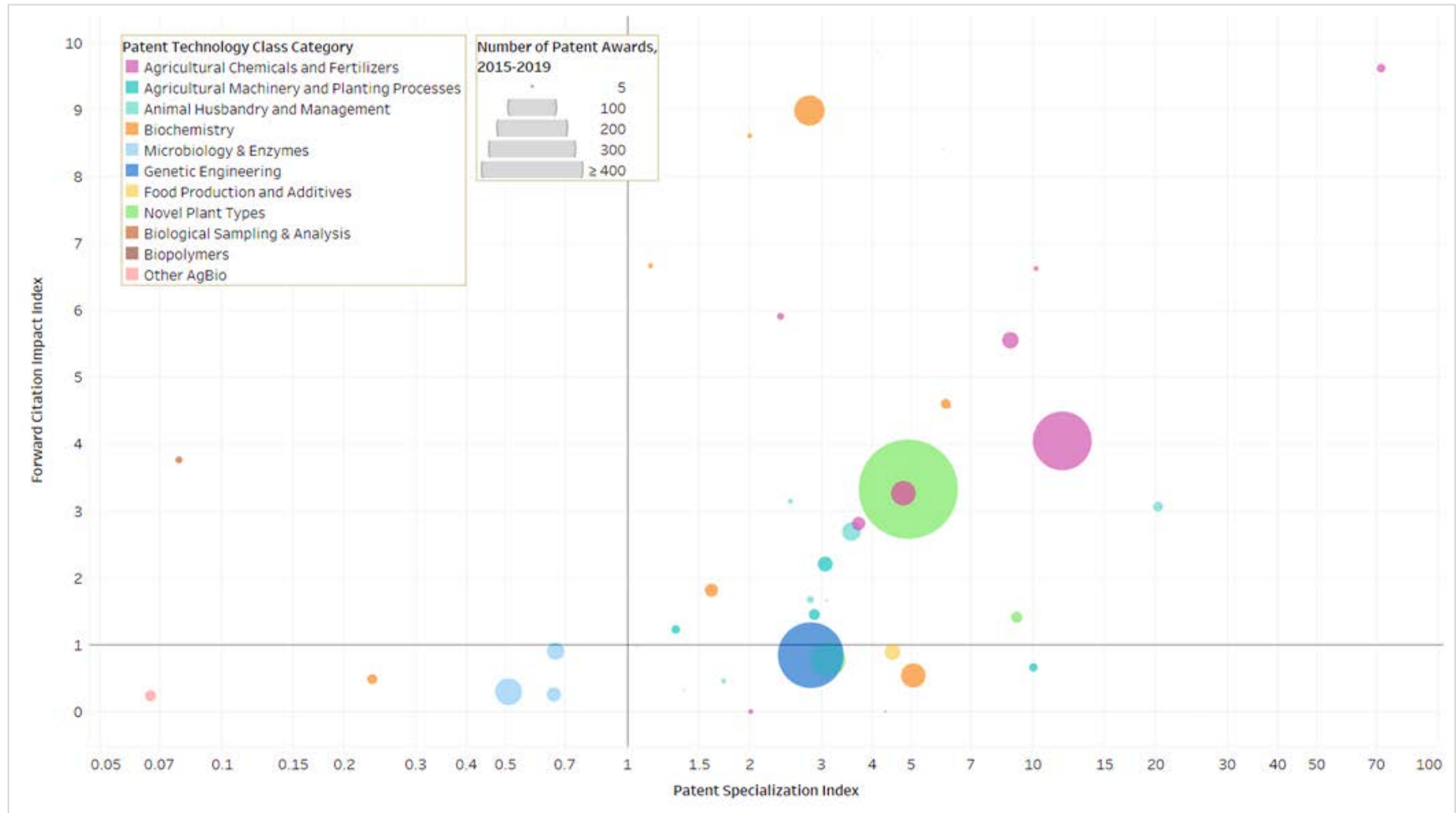
It is evident that Novel Plant Types, primarily hybrid corn/maize varieties, but also including soybean and wheat, is a standout area of high-volume, specialized patent activity for Indiana agbioscience also generating above-average forward innovation impacts.

Additional areas of significant patenting volume include the following:

- Genetic engineering compounds and promoters, primarily used for modulating gene expression for production of transgenic plant varieties (specialized, but not highly impactful in generating forward innovation).
- A variety of fungicide, herbicide, and insecticide compounds with specific synergistic or stability properties for use with crops (specialized and highly impactful in generating forward innovation).
- Key classes of biochemistry compounds primarily used in the preparation of pesticides and fungicides (specialized and extremely impactful in generating forward innovation).

Also evident is a presence of some microbiology and enzymology patenting activity related to assays for detection of transgenic and trait-associated biomarkers in plants as well as stem cell culture media, but activity there is not specialized or highly impactful in generating forward innovation.

Figure 15: Indiana Agbioscience Patenting—Profile of Major Technology Areas (2015–2019)

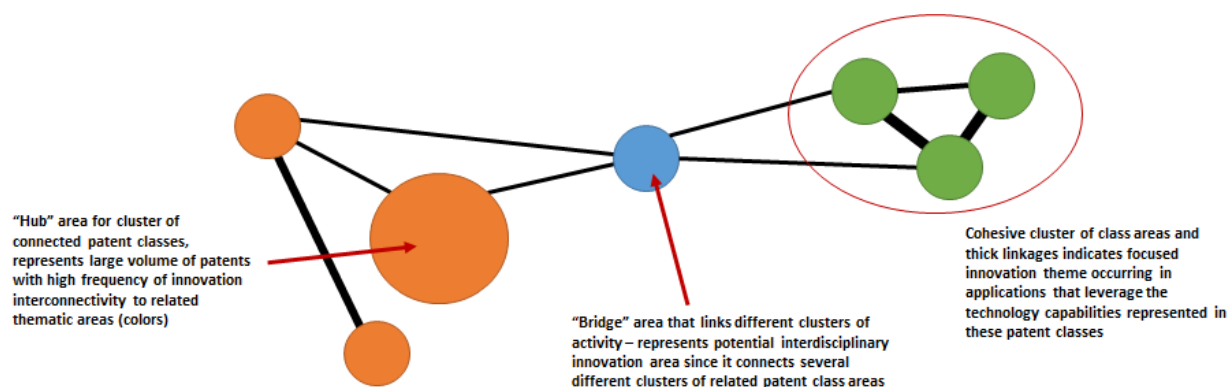


Source: TEConomy analysis of USPTO data.

Examining Technology Landscapes in Patents Using Innovation Networks

Patent records often list a variety of different technologies that are present within documentation of novel IP, representing combination technologies that can yield insights into the more detailed market applications of innovation activity. The variety of combination technologies present in broader regional patenting can be examined through connections in co-occurring technology area classifications present in patent records. The overall network formed by these connections provides a means to show how the “landscape” of innovative capabilities are organized in technology areas of interest and how patenting activity gives insight into cross-disciplinary linkages across broader themes (Figure 16).

Figure 16: Example of Network Formed by Patent Technology Class Areas



Bubbles indicate detailed patent class areas:

- Size of bubbles indicates number of patents in a given technology class area
- Color of bubbles indicates clusters of highly related classes connected by sets of common co-occurring technology areas.

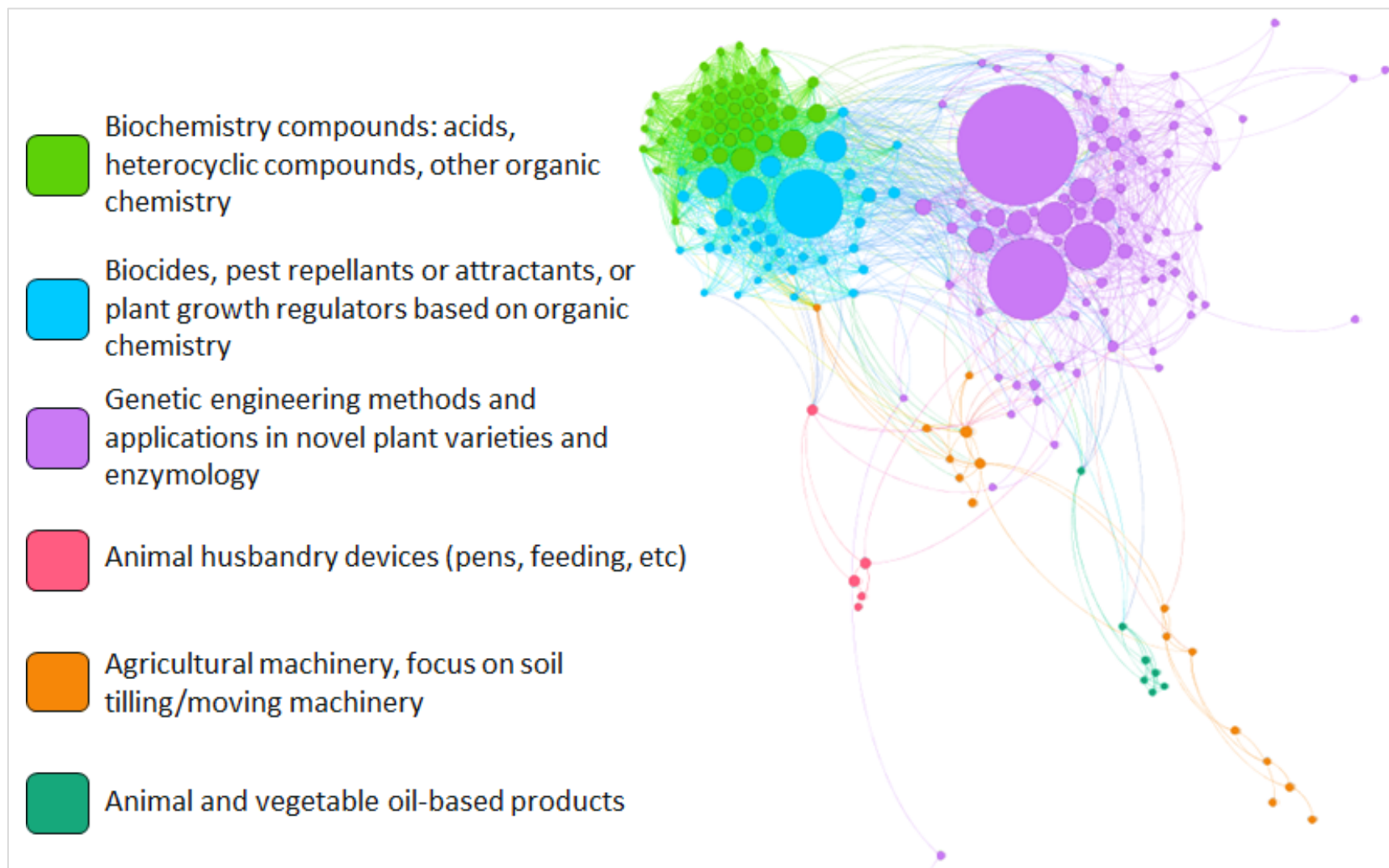
Lines indicate common connections between technology class areas listed on patent records:

- Thickness of lines indicates strength of connection as measured by the frequency of times the class combination appears in a set of patent data.

Source: TEconomy Partners, LLC.

Figure 17 shows the network formed by co-occurring technology “linkages” found in Indiana agbioscience patent records. The largest component of the network is involved in innovations pertaining to genetic engineering methods and applications in novel plant varieties and enzymology. Also large, and connecting to the novel plant varieties, is a crop chemistry-related cluster comprising biocides, pest repellants or attractants, or plant growth regulators based on organic chemistry. This latter cluster also nests closely with a major cluster of patents in biochemistry compounds. Other patent areas have much lower levels of frequency and less connectivity to the three large patent clusters. **It is quite clear from the patent network analysis, that the primary strength of Indiana’s applied agbioscience innovation (as measured by patents) is quite firmly rooted in plant science and associated agricultural chemicals development.**

Figure 17: Indiana Agbioscience Patenting: Technology Class Co-Occurrence Network



Source: TEconomy analysis of USPTO data.

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, TEconomy accessed data from the National Center for Education Statistics' Integrated Postsecondary Education Data System (NCES-IPEDS) database and used an occupation to degrees crosswalk developed by the National Crosswalk Service Center in Iowa. Table 11 shows that Indiana produced 1,033 graduates in 2018 with higher education degrees related to agbioscience and associated disciplines. This graduate output included: 116 Associate's degrees (12 percent); 595 Bachelor's degrees (59 percent); 128 Master's degrees (13 percent); 81 Doctoral (PhD) degrees (8 percent), and 85 Doctor of Veterinary Medicine degrees (8 percent). Table 11 lists degrees ranked by the combined number of graduates in the discipline (including Associates through Doctoral degrees).

Table 9. Graduate Output of Indiana Universities and Colleges in Fields Related to Agbiosciences (2018)

CIPTitle	Associate's degree	Bachelor's degree	Master's degree	Doctor's degree - research/scholarship	Doctor's degree - professional practice	2018 Total
Agricultural Business and Management, General	23	142				165
Animal Sciences, General		155	4	5		164
Agricultural Economics		39	50	13		102
Agricultural Engineering		65	19	15		99
Agriculture, General	85	9				94
Veterinary Medicine					85	85
Food Science		34	12	12		58
Nutrition Sciences		34	4	7		45
Agricultural Mechanization, General	3	27				30
Botany/Plant Biology		15	7	8		30
Agroecology and Sustainable Agriculture		21				21
Horticultural Science		9	5	5		19
Soil Science and Agronomy, General			8	10		18
Agricultural Communication/Journalism		14				14
Entomology		5	5	4		14
Veterinary Sciences/Veterinary Clinical Sciences, General			10			10
Plant Genetics		9				9
Farm/Farm and Ranch Management		6				6
Agricultural and Extension Education Services			4	2		6
Equestrian/Equine Studies		5				5
Applied Horticulture/Horticulture Operations, General	5					5
Turf and Turfgrass Management		4				4
Horse Husbandry/Equine Science and Management		2				2
AgBioscience-related Degree Totals	116	595	128	81	85	1,005

Source: TEconomy analysis of NCES IPEDS data.

It is useful to compare the four-year-and-above degree output across fields in Indiana with the identified academic research strengths and patenting strengths identified in this chapter—with this comparison performed to see if there is close alignment between research innovation areas in Indiana and agbioscience degree output. Tables 10 and 11 show the results of the comparison.

The largest mismatch between agbioscience degrees produced in Indiana and research strengths and patents in Indiana appears in the area of plant sciences. Including the entire Bachelor's and Graduate degree output in botany/plant biology, horticulture, and plant genetics (and even including entomology as often focused on applications to crops) only leads to identification of 42 undergraduate degrees and 34 graduate degrees in this area.

Table 10: Crosswalk of 2018 Graduate Output in Fields Relevant to Leading Publication Themes in Indiana

Leading Publication Areas	Bachelor's Degrees	Graduate Degrees
Total Agbioscience-Related Degrees	595	294
Agricultural Economics, Marketing, & Farm Management	187	63
Veterinary Medicine & Animal Health	162	104
Plant Science	42	34
Food Science	68	35
Water, Soils, & Environmental Science	21	18
Digital Agriculture	65	34

Source: TEconomy Partners, LLC. Note: Publication Area Degrees will not sum to Total Degrees.

Table 11: Crosswalk of 2018 Graduate Output in Fields Relevant to Leading Patenting Areas in Indiana

Leading Patent Areas	Bachelor's Degrees	Graduate Degrees
Total Agbioscience-Related Degrees	595	294
Agricultural Machinery and Planting Processes	92	34
Animal Husbandry and Management	7	95
Fertilizers & Agricultural Chemicals	0	0
Novel Plant Types	37	25
Food Production and Additives	68	35
Genetic Engineering, Microorganisms, or Enzymes	9	0

Source: TEconomy Partners, LLC. Note: Publication Area Degrees will not sum to Total Degrees.

Table 12 compares changes across key agbioscience degree disciplines in terms of number of degrees granted in 2012 and in 2018 – providing a percentage increase or decrease figure over the time period for bachelor's degrees and higher, and for doctoral degrees alone. Overall growth in key disciplines is evident in these data, with a 5.4 percent increase in all Bachelor's and Higher degrees awarded, and a robust 37.8 percent increase in awarded doctoral degrees.

Table 12: Comparison of 2012 and 2018 Graduate Output in Indiana Agbioscience Fields

College/University Degree Fields	IN Graduates (Bachelor's & Higher), 2012	IN Graduates (Bachelor's & Higher), 2018	Change (Percent) 2012-2018	IN Doctorate Degrees, 2012	IN Doctorate Degrees, 2018	Change (Percent) 2012-2018
Animal Sciences, General	142	164	15.5%	6	5	-16.7%
Agricultural Engineering	87	99	13.8%	14	15	7.1%
Food Science + Food Technology and Processing	47	58	23.4%	10	12	20.0%
Botany/Plant Biology	16	30	87.5%	2	8	300.0%
Agroecology and Sustainable Agriculture	1	21	2000.0%	0	0	--
Horticultural Science	32	19	-40.6%	4	5	25.0%
Soil Science and Agronomy, General	12	18	50.0%	2	10	400.0%
Entomology	14	14	0.0%	1	4	300.0%
Agriculture, General	6	9	50.0%	0	0	--
Plant Genetics	4	9	125.0%	0	0	--
Horse Husbandry/Equine Science and Management	1	2	100.0%	0	0	--
Agronomy and Crop Science	29	0	-100.0%	0	0	--
Animal Physiology	19	0	-100.0%	0	0	--
Total	410	443	5.4%	39	59	37.8%

Source: TEconomy analysis of NCES IPEDS data.

The top four disciplines in terms of absolute increase in number of Bachelor's and Higher degrees are:

- Animal Sciences, growing from 142 degrees in 2012 to 164 in 2018, an increase of 22 degrees.
- Agroecology and Sustainable Agriculture, growing from just 1 degree in 2012 to 21 in 2018, an increase of 20 degrees.
- Agricultural Engineering, growing from 87 degrees in 2012 to 99 degrees in 2018, an increase of 12 degrees.
- Food Science and Food Technology and Processing, growing from 47 degrees in 2012 to 58 in 2018, an increase of 11 degrees.

In terms of percentage increase in Bachelor's and Higher degrees awarded, the top three fields are:

- Agroecology and Sustainable Agriculture (2000 percent increase)
- Plant Genetics (125 percent Increase)
- Horse Husbandry/Equine Science and Management (100 percent increase)

Indiana's Workforce in the Agbiosciences as Defined by Occupation Groups

The Occupational Employment Statistics Program of the U.S. BLS provides detailed data on national and state employment and wages by occupational type. Shown on Table 13 are three groupings of occupations related to agricultural science with data for Indiana. It is evident that Indiana has a specialized concentration of agricultural engineers (LQ = 1.85); but, across most of the other occupations listed, the LQ is below 1.0 and thus indicative of fewer jobs in these occupational categories in Indiana than would be expected given national normative levels.

Table 13. Indiana's Agbioscience Innovation-Related Occupational Employment (2019)

Primary Agricultural Innovation-Related Occupations

Occ. Code	Occupation	Indiana Employment 2019	Indiana LQ	Indiana Hourly Wage Mean	Indiana Annual Wage Mean	U.S. Hourly Wage Mean	U.S. Annual Wage Mean
19-4010	Agricultural & Food Science Technicians	350	0.76	\$21.18	\$44,050	\$21.37	\$44,440
19-1012	Food Scientists & Technologists	260	0.92	\$36.95	\$78,860	\$36.63	\$76,190
45-2011	Agricultural Inspectors	200	0.69	\$19.90	\$41,390	\$22.67	\$47,160
17-2021	Agricultural Engineers	60	1.85	\$39.16	\$81,450	\$47.26	\$98,290
19-1011	Animal Scientists	60	1.07	\$37.40	\$77,780	\$32.96	\$68,570
Primary Occupations Subtotal		930	0.83				

Secondary Agricultural Innovation-Related Occupations

Occ. Code	Occupation	Indiana Employment 2019	Indiana LQ	Indiana Hourly Wage Mean	Indiana Annual Wage Mean	U.S. Hourly Wage Mean	U.S. Annual Wage Mean
29-1131	Veterinarians	1,560	1.00	\$43.88	\$91,260	\$50.39	\$104,820
19-4021	Biological Technicians	730	0.44	\$21.31	\$44,320	\$23.61	\$49,110
19-1021	Biochemists & Biophysicists	450	0.69	\$44.25	\$92,030	\$52.01	\$108,180
19-1022	Microbiologists	350	0.92	\$31.56	\$65,650	\$39.79	\$82,760
19-1031	Conservation Scientists	250	0.54	\$32.41	\$67,410	\$32.23	\$67,040
19-1023	Zoologists & Wildlife Biologists	120	0.30	\$26.36	\$54,830	\$32.31	\$67,200
Secondary Occupations Subtotal		3,460	0.67				

Other Associated Occupations

Occ. Code	Occupation	Indiana Employment 2019	Indiana LQ	Indiana Hourly Wage Mean	Indiana Annual Wage Mean	U.S. Hourly Wage Mean	U.S. Annual Wage Mean
31-9096	Veterinary Assistants & Laboratory Animal Caretakers	2,290	1.13	\$14.28	\$29,700	\$14.28	\$29,690
29-2056	Veterinary Technologists & Technicians	1,950	0.84	\$15.74	\$32,740	\$17.63	\$36,670
19-1029	Biological Scientists, All Other	580	0.69	\$32.74	\$68,100	\$42.11	\$87,590
45-2091	Agricultural Equipment Operators	580	1.03	\$17.52	\$36,440	\$16.01	\$33,300
39-2021	Animal Caretakers	4,540	1.02	\$11.70	\$24,330	\$13.01	\$27,060
45-2099	Agricultural Workers, All Other	70	0.51	\$11.20	\$23,290	\$16.31	\$33,930
Other Occupations Subtotal		10,010	0.97				

Source: TEconomy analysis of BLS Occupational Employment Statistics Program data.

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 disciplines related to agriculture and engineering. 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 advance agbioscience research and sustain 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) as well as Purdue alumnus, Akin Adesina, being awarded the World Food Prize in 2017. Purdue's commitment to agbioscience research results in a substantial base of activity, and Purdue is among the top tier of universities in performance of research with \$126.5 million in fiscal year 2018 in agricultural sciences research expenditures. 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 Institute.** The university's investment in plant science research at the launch of Purdue Moves in 2013 has generated tens of millions of dollars in new grants and gifts that have strengthened research programs and the university's ability to deploy discoveries for global impact. Turning data into decisions, and training others in Indiana and around the world to do so, is critical to increasing the efficiency, profitability, and sustainability of agriculture and food systems; and Purdue is seeking to lead the way. Over the first five years of the institute, the College of Agriculture has generated \$154 million in gifts and external grants.
- The college has also strengthened the university's research capacity in plant sciences by establishing the **Center for Plant Biology**, comprising a community of 36 faculty members across 7 departments. The center provides a dynamic training environment for graduate students, and 10 new basic plant science faculty have joined since 2016.
- Purdue is highly advanced in the digital agriculture space. An **Internet-of-Things (IoT) test bed** at the **Agronomy Center for Research and Education (ACRE)** is in place, enabling wireless access across the 1,400-acre research farm. Remote towers throughout the field capture real-time measurements such as greenhouse gas emissions.
- Two state-of-the-art phenotyping facilities are now online:
 - **Indiana Corn and Soybean Innovation Center:** This 25,500-square-foot field phenotyping facility at the ACRE opened in 2016 as a hub of phenomics research for plant breeders, engineers, computer

scientists, and aviation scientists. Thanks to a combined \$4 million investment from Indiana corn and soybean farmers, it is home to advanced technologies for plant processing, seed analysis, threshing and shelling, remote sensing, and data management. Since its opening, the center has welcomed 50 research labs; conducted 1,000 unmanned aerial vehicle (UAV) flights; hosted 7,000 visitors from 40 countries; and trained 25 Purdue Extension educators who are experimenting with new drone uses across the state.

- **Ag Alumni Seed Controlled Environment Phenotyping Facility:** This automated phenotyping facility opened in spring 2018 to run experiments under highly uniform growth conditions that cannot be easily controlled in the field. Its full range of sensing capabilities, including hyperspectral imagery (HSI), red-green-blue (RGB), shortwave infrared (SWIR), and computed tomography (CT), allows researchers to study below- and above-ground plant traits from seedlings to full-height corn. Since its opening, the facility has: run 36 experiments in 17 months; hosted 2,000 visitors; studied 10 plant species (including sorghum, corn, wheat, switchgrass, cereal rye, tomatoes, basil, kale, and garlic); and installed an X-ray CT scanner to nondestructively image roots in 3-D.
- Purdue established the **North American Plant Phenotyping Network (NAPPN)** and hosted its inaugural event.
- Launched **Ag-Celerator** in December 2015, a \$2 million plant sciences innovation fund, to provide critical start-up support for Purdue innovators looking to commercialize patented IP or Purdue plant science technologies. As of 2019, Ag-Celerator has funded 12 start-ups and invested \$655,000.
- Purdue broadened student reach and training through the following:
 - The **Molecular Agriculture Summer Institute (MASI)**, which began in 2014 to expose high school and undergraduate students to plant sciences and molecular agriculture research. This program attracts students into science, technology, engineering, and mathematics (STEM); promotes undergraduate research; and stimulates student and faculty collaboration. Since its inception, 59 undergraduates and 59 high school students have completed their respective programs.
 - A renovated student-centered learning facility named **Beck's Molecular Genetics Teaching Lab in Lilly Hall**. The lab accommodates twice the number of students in genetics laboratory courses each semester since 2015. A similar lab also was built for Biochemistry.
 - A nine-week paid internship called **ASPIRE (Ag Soy Product Innovation Realization & Entrepreneurship)** to allow student innovators to advance soy-based prototypes toward commercialization. Since May 2017, 15 interns have conducted research and participated in customer delivery activities.
- **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 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.
- **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 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 USDA-ARS Eastern Regional Research Center. Engineers and food scientists work together on biological target separation and concentration and development of 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.

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. The following are examples:

- **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.
- **The 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 GTAP is a global database describing bilateral trade patterns, production, consumption, and intermediate use of commodities and services.
- **Global to Local Analysis of Systems Sustainability (GLASS)** is a new effort to meet the Global Sustainable Development Goals on a changing planet with limited land and water resources. GLASS provides a network that highlights tradeoffs and synergies associated with policies tackling the sustainable development goals. They produce policy briefs and other actionable recommendations for achieving the sustainable development goals. NSF-funded GLASSnet is creating the infrastructure and open-source tools necessary to develop a self-sustaining community of researchers, partner organizations, and funders.

Multidisciplinary Collaborations Bring Digital Agriculture to the Forefront

Digital agriculture is becoming increasingly important as a sustainable avenue to advance agriculture’s future using data, science, and innovation. Purdue is well situated to be a leader in this field with its top 10 ranked colleges of agriculture and engineering and a commitment from university leadership to invest in the area of data science research and education, including a new \$40 million facility. Currently, Purdue has more than 80 faculty across 6 colleges working in the area of digital agriculture. Purdue has developed several initiatives and collaborations to leverage the university’s know-how with increasingly innovative technology in the digital agriculture and data science space. The following are examples:

- **IoT testbeds** are used at Purdue to conduct research to answer important research questions, often in real-world or near real-world environments. Currently, Purdue has ag IoT test beds at ACRE and within the new Agricultural and Biological Engineering Building on campus. This work is supported in part by the Wabash Heartland Innovation Network, which is also collaborating with researchers to build IoT test beds on farms in the 10-county region around Purdue.
- Purdue is a partner in a new **NSF-funded Engineering Research Center for the Internet of Things for Precision Agriculture (IoT4Ag)** where more than two dozen researchers from four institutions will work

together in three interconnected areas: agricultural sensor systems, communication and energy systems, and agricultural response systems.

Digital agriculture also plays a key role in a number of centers and initiatives across Purdue's campus, including the Center for Global Food Security, Open Agriculture Technology and Systems Center, Integrated Digital Forestry group, Open Ag Data Alliance, and the Center for Education and Research in Information Assurance and Security.

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 following:

- **The Horticulture Plant Growth Facility.** Opened in 1998, this facility includes 25 greenhouse rooms totaling 34,800 square feet, 2 air-conditioned growth rooms; 17 growth chambers; 5 walk-in coolers; a tissue culture laboratory; 3 teaching laboratories; and 4,500 square feet of headhouse space for offices, workspace, and storage.
- **The Agronomy Center for Research and Education (ACRE)** is a >1,000-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 ASREC 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 10 miles northwest of the Purdue campus.
- **The Food Science Pilot Lab** is a 9,000-square-foot facility that allows manufacturers to see how a process works before committing to full production. Wet chemistry, microbiology, and food product development laboratories are also available to solve related challenges. Capabilities include aseptic and thermal processing and packaging, equipment design and development, automated quality control/recipe management, process design, ultrasound applications/process improvement, in-line physical/chemical sensor evaluation, controlled/modified atmosphere, active and aseptic packaging, shelf-life studies, and sensory evaluation.

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, Purdue Climate Change Center, Bindley BioScience Center, Birck Nanotechnology Center, Center for the Environment, and the Burton D. Morgan Entrepreneurship Center. Discovery Park has now expanded to include the Discovery Park District where companies can co-locate while taking advantage of the research and talent at the university.

Purdue University as a Collaborative Hub for Agbioscience Industry

Making a difference in agriculture and ensuring that agriculture meets its commitment to solving global grand challenges mandate that new agricultural innovations are diffused, manufactured, or introduced to the marketplace. While Purdue Extension plays a critically important role in transferring knowledge and know-how, the university also sustains intensive relationships with agbioscience businesses, commodity groups, and entrepreneurs to ensure that 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 **Convergence Center for Innovation and Collaboration** in Purdue's Discovery Park District adjacent to campus is designed to serve as a "front door" to companies that seek to collaborate with Purdue. Currently, a number of agriculture companies have opened offices in the 145,000-square-foot building. From employing students to collaborating with Purdue faculty and researchers from across campus, this type of partnership fuels innovation for both the companies and Purdue students, faculty, and staff.
- **The Whistler Center for Carbohydrate Research** works in partnership with companies to extend uses of carbohydrates, hydrocolloids in general, other biopolymers, and cereals including research on the impact of carbohydrates on the microbiome. Partner companies include Corteva, Kraft, Cargill, Tate and Lyle, ConAgra Foods, General Mills, Pepsico, and others.
- New start-up companies have moved into **Purdue Research Park**. These include Inari, a biotech company developing next-generation seeds, and Solinftec, a global leader in digital agriculture.
- 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 the following:

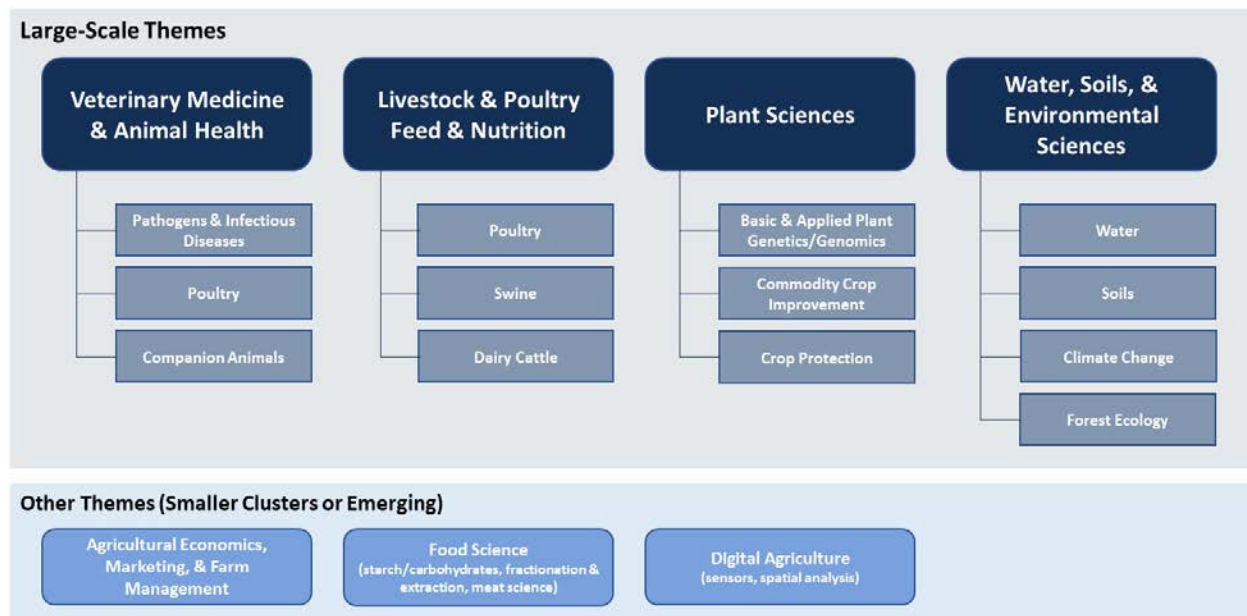
- **GRYFN**, a Purdue University-affiliated agbioscience start-up, offers precise geomatics solutions for coaligned and repeatable multisensory drone data collection. The company is using technology developed at Purdue and licensed through the Purdue Research Foundation Office of Technology Commercialization.
- **Heliponix LLC**, a Purdue University-affiliated start-up, designs, distributes, and supports direct-to-consumer, in-home greenhouses. Founded by Purdue Polytechnic Institute graduates, the company sells the GroPod Smart Garden Appliance, a small, fully automated, in-home greenhouse to grow daily servings of Pure Produce from subscription Seed Pods. Heliponix is a start-up from Purdue Foundry's Startup Class of 2017.

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 4 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 IV. Agbioscience Innovation in Indiana

Innovative Agbioscience Drivers in Indiana

As Chapter II shows, Indiana benefits from a diverse agbioscience profile. Chapter III demonstrates that the state also enjoys an agbioscience research base that is both broad in terms of its areas of interest, but also focused in certain areas of concentration and expertise in select categories. It is seen that, from an academic research perspective, key areas of strength can be found in:



From a patenting perspective, the key areas of activity concentrate around:



In general, the strengths identified in the above innovation analysis, when combined with the review of Indiana's agbioscience business profile, are supportive of the existing emphasis of AgriNovus Indiana that concentrates work across four principal platforms (Figure 18).

Figure 18: Indiana Agbioscience Innovation Platforms

Indiana Agbioscience Innovation Platforms			
Value-Added Food and Nutrition	Plant Science and Crop Protection	Agricultural Equipment, Technologies, and Systems	Animal Health and Nutrition
Establishments = 98 Employment = 17,295 Publications = 641 Patents = 57	Establishments = 32 Employment = 2,764 Publications = 1,637 Patents = 736	Establishments = 47 Employment = 2,769 Publications = 110 Patents = 118	Establishments = 21 Employment = 1,674 Publications = 887 Patents = 106

Source: TEconomy Partners, LLC.

Each of the four platforms, as determined through the core competency analysis, is a base for significant innovation activity in Indiana—and this can be seen in the summary publication and patent statistics for each platform in Figure 18. They each are also home to a significant base of industry establishments, ranging from a high of 98 establishments in the Value-Added Food and Nutrition platform, to a low of 21 in the Animal Health and Nutrition platform. Combined, there are 24,502 personnel employed in the innovative companies driving these platforms, with the largest concentration being in the Value-Added Food and Nutrition platform (17,295 personnel, 70.6 percent of all platform employment).

Each of the platforms is discussed in detail in the sections that follow.

Value-Added Food and Nutrition

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. The focus is on downstream, post-farmgate processing of agricultural output into value-added food, nutrition, and health products.

Typically referred to as the “food processing” sector, the conversion of agricultural products into value-added food products for delivery to consumers is a huge industry. While many foods (e.g., fruits and vegetables) may be shipped to market without further processing, a large volume of food commodities produced on farms need to be further processed for consumption. This downstream processing (i.e., food processing or food manufacturing) is generally divided into three macro categories:

- **Primary Food Processing**—whereby raw agricultural products are converted into foods that can be consumed or used as direct ingredients in further processing steps. Examples include the milling of wheat grains into flour or the deboning of fish.
- **Secondary Food Processing**—whereby ingredients produced through primary food processing are combined or further processed to create a food product. Examples include production of baked goods using flour, sugar, and other ingredients or the combination of ground meat with soy protein and spices to make sausage.
- **Tertiary Food Processing**—typically an industrial-scale process whereby ingredients are processed into packaged, shelf-stable finished meals and snacks. Examples include frozen meals, packaged snacks, etc.

In addition to direct food and beverage products, agricultural output can also be broken down and processed to extract specific nutrients or components of the product that are associated with applications to human health and wellness. Terms such as nutraceuticals, health supplements, and functional foods are used to describe products that may comprise food, or parts of a food, anticipated to provide medical or health benefits (beyond the basic energy requirements provided by the food).

Why Is This An Opportunity For Indiana?

Currently, there are 97 establishments identified in Indiana as engaged in value-added food and nutrition research and production with a significant employment base of 17,295. Example firms include ADM, AmeriQual, Artemis International, Cargill, Clabber Girl, Farbest Foods, Frito-Lay, Ingredion, Kerry Ingredients, Maple Leaf Farms, Mead Johnson, Park 100 Foods, Red Gold, Tate & Lyle, Tyson, and Weaver Popcorn.

Everyone has to eat, and so the food industry writ large enjoys a relatively stable and assured market demand. In addition, rising incomes in developed nations are providing an expanding pathway for consumers to incorporate more diversity, selectivity, and functional nutrition preferences into their diets. In the United States, the traditional factors influencing food selection have been price, taste, and convenience. However, segments of the consumer base are increasingly emerging that value other factors in their food choices—factors such as health and wellness, transparency in production processes,

social or environmental impact of food production, food miles and local food, organic production, etc. These trends provide opportunity for smaller, niche companies and large, processed-food companies alike to innovate and grow.

The global food processing market, according to research by Research and Markets is expected to reach an estimated \$4.1 trillion by 2024 with a compound annual growth rate (CAGR) of 4.3 percent from 2019 to 2024. Within the United States, market researchers at Statista place the food industry at \$924.4 billion in 2020, and project it to grow to \$1.01 trillion by 2025 (a CAGR of 1.8 percent).

The 2015 report noted as follows:

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.⁸ 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.⁹

The opportunities for industry growth through functional foods and nutraceuticals have also been supplemented further by significant growth in consumer demand for organic-certified products and, to a lesser degree, by interests in locally produced foods and foods with transparency in their sourcing. Consumers, especially millennials, have become more “food aware”; and the

COVID-19 and the Food Industry

The long-term impacts of the pandemic on the food sector remain to be seen. During the pandemic, the consumption of packaged foods and meal preparation at home have increased as people social distance and those companies that supply the grocery store or direct-to-consumer delivered food products (such as meal kits and subscription food products) have generally done well. The inverse has been the case for those companies that have a significant base of business in supplying food ingredients and finished food products to the hospitality or commercial/institutional food markets.

The impact of COVID-19 may also generate increased demand for healthier foods and functional food products. Awareness of the challenges presented by diet-related health risk factors (such as Type 2 diabetes and obesity) and the benefits of potential diet-related boosting of the immune system may affect demand for healthier foods and functional food products (such as probiotics).

The pandemic has also impacted the industry in ways beyond consumer demand. Multiple food-processing plants experienced COVID-19 outbreaks in their facilities, and food supply chains have been impacted by both production and logistics challenges that have occurred. The challenges experienced by some food-processing companies may spur greater investment in robotics and other automation technologies (to lessen dependence on human labor) and in digital supply-chain monitoring systems to provide greater supply-chain transparency and hedging against supply disruptions.

⁸ BCC Research. Nutraceuticals: Global Markets and Processing Technologies. July 2011.

⁹ Ibid.

growth in popularity of food network shows, celebrity chefs, and “Instagram” culture around food further creates interest and demand.

The anticipated growth in functional foods and nutraceuticals is expected to substantially eclipse that of food manufacturing in general. Recent research published by BCC Research notes as follows:¹⁰

- The global nutraceutical market should be expected to grow from \$230.9 billion in 2018 to \$336.1 billion by 2023 at a CAGR of 7.8 percent, from 2018 to 2023.
- The functional beverages segment of the global nutraceutical market is expected to grow from over \$83.1 billion in 2018 to \$124.4 billion in 2023 at a CAGR of 8.4 percent, from 2018 to 2023.
- The functional food segment of the global nutraceutical market is expected to grow from \$75.1 billion in 2018 to \$110.9 billion in 2023 at a CAGR of 8.1 percent, from 2018 to 2023.

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 represents potential pathways to increasing the value of Indiana’s commodities and specialty agricultural products. It is also complementary to Indiana’s major cluster of firms in biopharmaceuticals and health products.

Recent Innovation Performance: Value-Added Food and Nutrition

Research and Innovation Output (2015–2019)	
Research Publications	<p>Total Publications: 641</p> <p>Key Disciplines: Food Science and Technology, Plant Sciences, Agriculture & Dairy/Animal Science, Horticulture, Agricultural Engineering, and Multidisciplinary Agriculture.</p> <p>Key Corporate Research: Mead Johnson—4 publications in this Platform. Nestle (Switzerland)—14 publications in this Platform.</p>
Patents	<p>Patents Assigned to Indiana Companies: 57 Patents Assigned to Indiana Inventors: 112</p> <p>Key Corporate Assignees: Mead Johnson Nutrition—14 Core Patents; 8 Related Patents (Medical Preparations); 36 Total Patents</p>

¹⁰ BCC Research. Nutraceuticals: Global Markets to 2023. July 2018.

Innovation Resources and Capital (2015–2019)	
USDA-Funded Research (non-SBIR)	Purdue University —12 Awards—\$4,394,578 State Total —12 Awards—\$4,394,578
SBIR Awards	One Award JUA Technologies International LLC 2019 Phase I—\$100,000 <i>Smart Multipurpose Solar Dehydration Device for Value Addition to Specialty Crops</i>
Angel & Venture Capital	Summary Companies—23 Deals—40 Investment—\$57.94 million By Deal Type Pre-Seed—3 Deals—\$40,000 Angel—26 Deals—\$28.88 million Seed—2 Deals—\$3.08 million Early Stage—6 Deals—\$13.65 million Later Stage—3 Deals—\$12.29 million

Source: TEconomy Partners, LLC.

Indiana companies have a strong base of innovation within value-added food and nutrition products. Multiple companies are actively engaged in research and commercialization of new products. Notably, since the 2015 report (in which it was noted that there were no venture capital deals in the sector in Indiana), risk capital investments in Indiana-based food and associated companies have increased substantially, with 34 funding deals valued at \$42.18 million occurring from 2015 to 2019. This represents strong evidence for the power and promise of this sector for Indiana’s agbioscience-based economic development.

Companies that are Actively Involved with this Innovation Sector

Company Name	Innovation Area Descriptions
A. M. Manufacturing Company	A.M. Manufacturing Company is automating the bakery industry with equipment inventions that turn pizza crusts, tortilla shells, and bagels into mass-produced foods.
AccuTemp Products Inc.	AccuTemp Products Inc. produces innovative, technology-based equipment solutions for the foodservice industry.
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.
Agricor Inc.	Agricor Inc. is a miller of certified organic, non-GMO (genetically modified organism), and conventional dry-milled corn products that are then sold to food, industrial, companion animal, and feed customers worldwide.

Company Name	Innovation Area Descriptions
Albanese Confectionery Group Inc.	Albanese Confectionery Group Inc. is a manufacturer, retailer, and distributor of gummies, chocolates, and other confectioneries.
American Griddle Corporation	American Griddle Corporation is a manufacturer of griddles. Its patented Steam Shell Technology has helped revolutionize the foodservice industry, allowing foods to be cooked with uniform temperatures, thereby creating better-tasting and more consistent results.
AmeriQual Group LLC	AmeriQual Group LLC is a leader in shelf-stable food production processes and products, including thermal-processed pouch products for Meal, Ready-to-Eat (MRE) and Humanitarian Daily Rations (HDR) for the U.S. Department of Defense. 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.
AquaBounty Technologies Inc.	AquaBounty Technologies Inc. is a leader in the field of land-based aquaculture and the use of technology for improving its productivity and sustainability. The company's objective is to ensure the availability of high-quality seafood to meet global consumer demand, while addressing critical production constraints in the most popular farmed species.
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.
Ash & Elm Cider Company	Ash & Elm Cider Company produces quality ciders using apples from around the Midwest and is working to cultivate the market for craft cider in Indiana.
Blue Marble Cocktails	Blue Marble Cocktails offers premium spiked seltzers using vodka instead of beer malt to create beverages with only 95 calories. Blue Marble is committed to ensuring that the products are both high quality and earth friendly, using recyclable packaging and working with organizations dedicated to ocean conservation.
BrewLogix (fka SteadyServ)	BrewLogix is a provider of online beer information and data collection services, providing patented keg sensors for craft beers, distributors, and on-premise retailers in the beer, kombucha, and cold draft coffee industries.
Butterfield Foods LLC	Butterfield Foods LLC is an USDA-inspected, private-label, food production company. Products include a variety of entrees and side dishes, soups and sauces, hand-pulled meat products, and sandwiches and salads.
Cardinal Spirits	Cardinal Spirits is a craft distillery that makes vodkas, gins, rums, liqueurs, and canned cocktails utilizing only botanicals, fruits, and spices for flavoring and locally sourced ingredients whenever possible.
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.

Company Name	Innovation Area Descriptions
Carmel Engineering Inc.	Carmel Engineering Inc. designs, engineers, and manufactures custom equipment and systems for the food and beverage processing industry as well as other diverse manufacturing industries.
Chapman's Brewing Company	Chapman's Brewing Company is a craft brewery that also has five taprooms across Northern Indiana.
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.
CraftMark Bakery	CraftMark Bakery is a commercial bakery partner producing frozen bread dough, frozen cookie dough, and ready-to-eat flatbread by combining R&D expertise with process innovation to create bakery solutions for foodservice and in-store bakery customers.
Crazy Horse Hops LLC	Crazy Horse Hops LLC is Indiana's largest producer, processor, and broker of hops, serving as an outlet for other growers as a centralized processing facility.
Creighton Brothers	Creighton Brothers is a major producer and processor of eggs.
Debrand Inc.	Debrand Inc. manufactures, distributes, and retails a variety of chocolates.
DSTest Laboratories	DSTest Laboratories help manufacturers of natural ingredients, nutraceuticals, and dietary supplements to produce and certify the potency (biological activity) of their products.
Epogee	Epogee is an innovative food ingredients company, having developed a patented fat replacement technology, that partners with food manufactures to improve nutrition, taste, and performance in a wide range of food applications.
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.
Farm Boy Meats of Evansville Inc.	Farm Boy Food Service is a food distributor. What began in 1952 as a meat-packing operation has grown into one of the largest independent food distributors in the state of Indiana.
Flavor Burst Co. LLP	Flavor Burst is a manufacturer of flavor and candy delivery equipment for frozen confections, designing and building multi-flavoring systems, which integrate with existing soft-serve, slush, frozen carbonated beverage, or milkshake freezers.
Frito-Lay Inc.	Frito-Lay Inc. manufactures, markets, and sells corn chips, potato chips, and other snack foods.
G and G Peppers LLC	G and G Peppers LLC grows, processes, and stores jalapeno, cherry, banana, and habanero peppers.
Geo. Pfau's Sons Company Inc.	Geo. Pfau's Sons Company Inc. processes animal oils, including fish and other marine animal oils, for a variety of end uses.

Company Name	Innovation Area Descriptions
Green River Greenhouse LLC	Green River Greenhouse LLC is a sustainable agriculture farm dedicated to producing 100% certified organic produce and farm-raised tilapia for nearby communities.
Green Sense Farms Holdings Inc.	Green Sense Farms Holdings Inc. provides turnkey controlled environment agriculture solutions by designing and building vertical farms, greenhouses, and integrated facilities.
Hard Truth Distilling Company	Hard Truth Distilling Co. operates a state-of-the-art distillery producing a variety of premium spirits and bringing them to market.
Hearthside Food Solutions	Hearthside Food Solutions is the industry's largest contract manufacturer and the largest private bakery in the United States. Founded in 2009, it is one of the youngest and fastest-growing companies in the industry.
Heartland Food Products Group	Heartland Food Products Group is a global leader in the consumer packaged goods industry, producing low-calorie sweeteners, coffee, coffee creamers, and liquid water enhancers.
Heliponix LLC	Heliponix LLC, a Purdue University–affiliated start-up, sells the GroPod Smart Garden Appliance—a small, fully automated, in-home greenhouse to grow daily servings of produce from subscription seed pods.
Hotel Tango Whiskey	Hotel Tango Whiskey produces nine quality spirits, and with funding secured earlier this year, it plans to open a second tasting room and expand its retail presence in Indiana.
HRR Enterprises Inc.	HRR Enterprises is a privately owned, safe quality foods (SQF) certified, beef processing company, specializing in meat-packaging and food-processing techniques, serving as one of the oldest independent renderers in the United States.
Indiana Packers Corporation	Indiana Packers Corporation is a pork-production and -packaging company.
Indiana Whiskey Company	The Indiana Whiskey Company is a distillery that produces small-batch whiskeys.
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.
Inventure Foods	Inventure Foods (formerly known as The Inventure Group) is a manufacturer producing a range of savory snack foods as well as smoothies, frozen berries, and frozen coffee.
IOM Grain	IOM Grain is a food-grade facility that specializes in cleaning and packaging high-quality non-GMO soybeans for domestic and international food manufacturers.
Jones Popcorn Inc.	Jones Popcorn Inc. (trade name Clark's Snacks) manufactures popcorn snacks as well as providing packaging and testing services.

Company Name	Innovation Area Descriptions
JUA Technologies International	JUA Technologies International, a Purdue-affiliated company, develops affordable, solar-powered crop-drying devices that dry fresh foods into high-quality, shelf-stable food products, reducing food loss due to spoilage.
Kerry Ingredients Inc.	Kerry Ingredients, located in Evansville, is a regional coating plant for Kerry Ingredients North America. Kerry Ingredients North America, based in Beloit, Wisconsin, is a member of the Kerry Group, a global food ingredients, consumer foods, and flavors company based in Kerry, Ireland.
Lewis Brothers Bakeries Inc.	Lewis Brothers Bakeries is a leading producer of baked goods anchored by its flagship brands Bunny Bread, Gateway, Hartford Farms, Healthy Life, and Indiana Spud potato bread. The company's products include whole grain and white breads, buns, muffins, and bagels.
Maple Leaf Farms	Maple Leaf Farms is the leading producer of quality duck products, supplying consumers, retail, and foodservice markets throughout the world with innovative, value-added foods.
Mariah Foods Corp.	Mariah Foods Corp. (trade name Peer Foods) is a meat-packing plant.
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.
Middlebury Cheese Co. LLC	Middlebury Cheese Company LLC is a cheese manufacturer.
Miller Poultry	Miller Poultry is a vertically integrated poultry company.
Monogram Frozen Foods LLC	Monogram Frozen Foods LLC manufactures meat snacks, corn dogs, pre-cooked bacon, smoked sausage, appetizers, and other value-added products.
Morgan Foods	Morgan Foods engages primarily in the development and production of canned store-brand food items.
MPS Egg Farms	MPS Egg Farms is one of the largest shell egg producers in the United States.
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.
New Day Craft	New Day Craft is a maker of modern craft mead and hard cider.
Newfangled Confections	Newfangled Confections makes hand-crafted chocolates.
NouvEau Inc.	NouvEau Inc. is a patent and IP holding company for license of the manufacture and branding of a luxury line of non-alcoholic beverages.
NutraMaize LLC	NutraMaize is commercializing a more nutritious, better-tasting, variety of non-GMO corn that possesses a deep orange color, which is produced by its high carotenoid content. NutraMaize is launching a line of milled products (grits, polenta, corn meal) that will be sold to foodservice and consumers. The variety

Company Name	Innovation Area Descriptions
	was developed at Purdue as part of an ongoing humanitarian effort to relieve global vitamin A deficiencies.
PacMoore Products Inc.	PacMoore is a contract manufacturer that provides tolling and turnkey processing of dry ingredients and finished products to ingredient manufacturers, consumer packaged goods, private label, and foodservice customers.
Park 100 Foods Inc.	Park 100 Foods is a manufacturer of custom-formulated, frozen soups, sauces, chili, and side dishes.
Perfection Bakeries Inc.	Perfection Bakeries Inc., doing business as Aunt Millie's Bakeries, produces and distributes bakery products, including breads, buns, rolls, muffins, and bagels.
Phytoption LLC	Phytoption LLC is a producer of all natural food coloring, and also provides technical services for product formulation and processing design.
Quaff ON! Brewing Company	Quaff ON! Brewing Company brews and distributes hand-crafted beers.
Rad Brewing Co.	Rad Brewing Co. is a microbrewery.
Real Food Blends	Real Food Blends makes meals for people with feeding tubes. The meals are free of corn syrup and preservatives, shelf stable, and covered by many insurance plans.
Red Gold	Red Gold produces a variety of canned tomato products for the foodservice industry.
Richmond Baking Co.	Richmond Baking offers breadings systems, dessert crumbs, ice cream inclusions, and contract baking and packaging services.
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.
SmithFoods Richmond Inc.	SmithFoods Richmond Inc. is a national food manufacturer and distributor of dairy and nondairy fluid products. The company serves national, regional, and local customers through a significant footprint covering the Midwest and Eastern United States. Prior to becoming SmithFoods Richmond Inc., it was Wayne Dairy, which began operation in Richmond in 1921.
SoChatti (aka Trade Secret Chocolates LLC)	SoChatti, a chocolate start-up company, has created a new chocolate experience by using a proprietary flavor preservation method that captures and maintains the best flavors of chocolate and packages it to be eaten in melted form. Due to its process and packaging, SoChatti's chocolate is shelf stable for up to two years without the use of preservatives, can be stored at temperatures up to 120°F, and can be subjected to repeated thermal cycling without degradation.
Switchyard Brewery	Switchyard Brewery is a craft brewery in Bloomington that includes a co-working space that encourages other entrepreneurs to create great things.

Company Name	Innovation Area Descriptions
Tate & Lyle Ingredients Americas LLC	Tate & Lyle is a multinational starch manufacturer and wet corn mill that also produces animal feed and ingredients for the food and beverage industries.
Tyson Foods Inc.	Indiana operations of Tyson Foods Inc. include a feed mill, poultry- and other meat-processing plants, and a manufacturing center for corn and flour tortillas.
Urschel Laboratories Inc.	Urschel manufactures and sells commercial cutting equipment to the food-processing and allied industries.
Weaver Popcorn Company	Weaver Popcorn is a producer of microwave and concession popcorn.
West Fork Whiskey Company	West Fork Whiskey Company is a distillery.
Weston Foods US Inc.	Weston Foods produces fresh and frozen baked foods through its subsidiaries Maplehurst Bakeries, Interbake Foods, Norse Dairy Systems, and ACE Bakery.
Wicks Pies Inc.	Wicks Pies Inc. is a commercial bakery known for Sugar Cream Pie and pie crusts.
Zachary Confections Inc.	Zachary Confections Inc. manufactures confections.
Zentis North America Operating LLC	Zentis North America Operating LLC specializes in the production of fruit jams, confectionery, fruit and cereal preparations, mousse, and baby food.

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. Companies in the sector 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.

Since 2015, the sector has experienced increased application of biotechnology with innovations occurring in new biological control products, processes, and methods designed to control crop pests, weeds, and plant diseases. There is also considerable expanding interest in plant-microbe symbiosis and the role that the microbiome in the soil and on/within plants may be used or amended to promote improved productivity.

Why Is This An Opportunity For Indiana?

Currently, 32 establishments with 2,764 employees are classified into this innovation platform. Example firms include Ag Alumni Seed, Agdia, AgReliant Genetics, Beck's Hybrids, Corteva, Lord's Seeds, SePRO Corporation, Remington Seeds, and Tom Farms.

Feeding an expanding global population and meeting global food demand, while preserving natural resources, are intense challenges for humankind. Estimates are that global food production will need to increase 70 percent by 2050 to meet population and wealth-driven demand, and this will have to be achieved without increasing agricultural land acreage and water consumption.¹¹ 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.

April 2019 projections by the Business Research Company (BRC) place the global market for crop agriculture at \$4.62 trillion.¹² Crop production experienced a strong CAGR of 4.1 percent during 2014–2018, and the industry sector was projected by BRC to grow at a higher CAGR of 5.5 percent during 2018–2022. COVID-19's impact on supply chains has, however, caused revisions to these numbers (see sidebar), although rapid recovery and growth in the sector is expected post COVID-19.

One way to meet this increased global demand is through innovation in plant science and crop protection technologies. For example, the agricultural chemicals sector of the market (comprising fertilizer and crop protection products) is projected by BCC Research to grow steadily¹³:

- The global market for agrochemicals reached \$243.1 billion in 2019 and should reach \$299.8 billion by 2024, at a CAGR of 4.3 percent for the period of 2019–2024.
- The fertilizer market reached \$174.5 billion in 2019 and should reach \$212.3 billion by 2024 at a CAGR of 4.0 percent through 2024.

COVID-19 and Agriculture

The global agriculture market is expected to decline from \$9997.0 billion to \$9890.0 billion in 2020 at a CAGR of -1.08%, this is due to disruption in supply chains and decline in consumption as a result of trade restrictions and lockdowns imposed across countries owing to the COVID-19 outbreak. Farmers faced difficulties in harvesting, marketing their produce and export of agricultural produce declined significantly as countries imposed restrictions on cross border trade. The market is then expected to recover and grow at a CAGR of 7.16% from 2020 to reach \$12168.3 billion in 2023.

BRC. Agriculture Global Market Briefing 2020-30: Covid-19 Impact and Recovery. 2020.

¹¹ World Resources Institute. *Creating a Sustainable Food Future*. 2013.

¹² Business Research Company. *Agriculture Market Global Briefing 2019*. April 2019.

¹³ BCC Research. *Global Markets for Agrochemicals*. January 2020.

- The pesticide market reached \$68.6 billion in 2019 and should reach \$87.5 billion by 2024 at a CAGR of 5.0 percent through 2024.

Agricultural biotechnology is another increasingly important component of the market. Biotechnology tools, genomics-enabled products, and biologicals all play a role in the sector. Biotechnology tools include DNA sequencing, biochips, RNA interference, synthetic biology, and gene editing. Genomics-enabled products include biotech seeds and synthetic biology-enabled products. Biologicals include biopesticides, biostimulants, and genetic biologicals. BCC Research projects significant growth in the biotechnology component of the market, noting as follows:

The global agricultural biotechnology market was \$50.5 billion in 2019 and is growing at a compound annual growth rate (CAGR) of 7.4 percent, to reach a forecast value of \$72.2 billion in 2024. Key factors driving growth in this industry include rising demand for biotech seeds that can deliver higher yields and better resistance to plant stresses and threats; emergence of a spectrum of enabling biotechnologies; and a growing demand for environmentally friendly crop protection products.¹⁴

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.

Recent Innovation Performance: Plant Science and Crop Protection

Research and Innovation Output (2015–2019)	
Research Publications	<p>Total Publications: 1,637</p> <p>Key Disciplines: Plant Sciences, Agronomy, Horticulture, Entomology, Forestry, Soil Science and Biochemistry/Molecular Biology.</p> <p>Key Corporate Research: Corteva (including Dow AgroSciences and DuPont Pioneer)—225 publications in this Platform. Agdia—7 publications in this Platform.</p>
Patents	<p>Patents Assigned to Indiana Companies: 736 Patents Assigned to Indiana Inventors: 1,174</p> <p>Key Corporate Assignees: Corteva (including Dow AgroSciences and DuPont Pioneer)—542 in this Platform; 798 Total</p>

¹⁴ BCC Research. Agricultural Biotechnology: Emerging Technologies and Global Markets. April 2020.

Innovation Resources and Capital (2015–2019)	
USDA-Funded Research (non-SBIR)	Purdue University —30 Awards—\$14,920,722 Indiana University —7 Awards—\$1,565,830 University of Notre Dame —2 Awards—\$710,000 State Total —39 Awards—\$17,196,552
SBIR Awards	Three Awards Agdia Inc. 2018 Phase I—\$83,751 <i>Rapid Identification of Tobacco Rattle Virus in Potato and Ornamental Hosts Using Isothermal Amplification and a Hand-Held Fluorometric Device</i> Biomineral Systems LLC 2018 Phase I—\$100,000 <i>Phosphorus Biofertilizer for Sustainable Crop Production</i> 2017 Phase I—\$100,000 <i>Nitrogen Biofertilizer for Sustainable Agriculture</i>
Angel & Venture Capital	Summary Companies—1 Deals—1 Investment—\$3.26 million By Deal Type Angel—1 Deal—\$3.26 million

Source: TEconomy Partners, LLC.

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.
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.
Biodyne USA	Biodyne USA is an environmental biotechnology company focused on harnessing the power of naturally occurring, beneficial microorganisms and other sustainable technologies for use in a variety of agricultural and environmental applications.

Company Name	Innovation Area Descriptions
Corteva Agriscience	Corteva Agriscience provides farmers around the world a balanced and diverse mix of seed, crop protection, and digital solutions focused on maximizing productivity to enhance yield and profitability. Corteva Agriscience became an independent public company in 2019 and was previously the Agriculture Division of DowDuPont.
Inari	Inari Agriculture, a biotechnology company developing next-generation seeds, has opened the Seed Foundry in West Lafayette to support the introduction of gene-edited hybrid corn and soybean varieties with improved yield results and reduced water and fertilizer requirements.
Italpollina	Italpollina is a world leader in the production and marketing of organic fertilizers, beneficial microbials, and biostimulants of plant origin for organic and conventional farming.
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.
Bayer (fka Monsanto)	Bayer 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	Specialty Hybrids provides corn, soybean, and alfalfa seeds and seed protection products.
Spectrum Non-GMO Seed	Spectrum Seed specializes in non-GMO seed for corn crops.
Syngenta	Syngenta provides essential inputs to growers: crop protection, seeds, seed treatments, and traits. The company's goal is to be the leading global provider of innovative products for every step of the agronomic process and to understand their interplay and optimize the results for growers and the food chain.
Tom Farms	Tom Farms is a global production, sales, and service operation, specializing in seed corn, corn, and soybeans. It is a leading supplier of seed corn.
Vertellus	Vertellus produces specialty chemicals to be used in markets including agrochemicals, nutrition, pharmaceuticals, and agriculture.

Agricultural Equipment, Technologies, and Systems

What Does This Sector Do?

Agricultural production and the downstream processing of agricultural outputs into value-added products requires the design, engineering, and manufacturing 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.

Many areas in the equipment and technology space are seeing significant innovation-based growth—especially in the integration of digital tools and analytics into agricultural production systems. The terms “precision farming,” “digital agriculture,” and, more generally, “agtech” are being used to describe the implementation of new technologies that combine equipment, sensors, geospatial positioning systems, data analytics, and other technologies to enable the variable and precise application of inputs to specific field and plant conditions, and more generally enable more efficient, data-driven decisions in farm management.

The implementation of automation solutions for production agriculture, agricultural processing, and food processing is also a place where convergence between physical and cyber systems is proving enabling of efficiencies. Robot-based automation in the field, as well as in processing facilities, is becoming a reality; and it is anticipated that development and adoption of automation technologies will be accelerated by several factors: the growing challenge of finding labor for lower wage occupations, the disruptive challenges to production caused by events such as COVID-19 limiting human labor capacity, and the potential productivity gains that can occur through robotics and automated processes.

Why Is This An Opportunity For Indiana?

Currently, 47 establishments with 2,769 employees are classified into this innovation sector. Example firms include Advanced Agrilytics, Banjo Corporation, CTB Inc.; DTN, Earthway Products, Equipment Technologies, Soil-Max, Total Control Systems, Trellis Growing Systems, Rabbit Tractors, Rogo, The Bee Corp, and Ziggity Systems.

The agricultural equipment and production technology sector is experiencing significant innovation activity. Advancements in areas including robotics, artificial intelligence (AI), machine vision, precision satellite telemetry, low-cost sensing systems, the IoT, and high-speed data analytics are combining to create substantial new business development and expansion opportunities.

With approximately two million individual farms in the United States, and a far larger international market, opportunities for finding customers for new and emerging innovative technologies are strong. Evidence for the promise of opportunities in the digital agriculture equipment and systems space can be seen in the fact that multiple risk-capital investment funds have been stood up to invest in the space,

and large companies are active in seeking acquisitions of promising new growth ventures. Most of the growth is coming from the agtech/digital convergence space, more than it is traditional agricultural production equipment. The number of U.S. farms has been declining (partly because of farm consolidation into larger farms, but also due to suburban encroachment and associated development) and so the market for traditional equipment is likely to be more limited in terms of growth.

The precision farming technologies market has certainly experienced significant recent growth, and robust further growth is anticipated with major U.S. land-grant research universities and a broad range of existing and new corporations engaged in the space. Adoption of applications and technologies such as field yield maps, location yield monitoring, soil condition measurement, aerial imagery, and variable rate applications using global positioning systems (GPS), etc., combined with intelligent analytics platforms, suggests a potential for the next green revolution, serving as a pathway for increasing yield while using inputs much more efficiently, and having the parallel benefit of reducing negative environmental externalities associated with excess agricultural inputs use. Companies involved in this industry space are diverse, providing a range of technologies such as automation and control systems, sensing and device monitoring, guidance and spatial analysis systems, and integrated farm decision/management software. Applications for precision and digital agriculture are being found not only in crop production, but also in animal agriculture—with activities in areas such as robotic milking, automated livestock feed systems, animal health surveillance, and environmental control.

Recent research by BCC Research places the global market for precision farming technologies at \$5.2 billion in 2019 with the market expected to grow to \$9.4 billion by 2024, for a strong CAGR of 12.6 percent for the period of 2019–2024.¹⁵ BCC estimates as follows:

- The global market for precision farming **hardware** technologies should grow from \$3.2 billion in 2019 to \$5.4 billion by 2024, with a CAGR of 10.8 percent for the period of 2019–2024.
- The global market for precision farming **software** technologies should grow from \$2.0 billion in 2019 to \$4.1 billion by 2024, with a CAGR of 15.2 percent for the period of 2019–2024.

While precision agricultural production technologies receive significant press, cyber-physical systems trends also are evident in post-farmgate processing of agricultural output. Driven by a need to increase productivity, and concerns over labor availability and workplace safety, processing companies are increasingly turning to automation. In the meat-processing sector, companies such as Tyson have invested significantly in R&D to advance automation solutions for processing. Located in Springdale, Arkansas, for example, Tyson's Manufacturing Automation Center is developing automated and robotic solutions for the meat packer's food production plants, with engineers focused on developing automation technologies for physically demanding, highly repetitive, or dangerous jobs. A recent article reports Tyson having invested more than \$215 million in automation and robotics during the past five years.¹⁶ Interest in automation was advancing in the sector before COVID-19 impacted the processing workforce, and experience during the pandemic is anticipated to accelerate corporate investments in automation in food processing to help mitigate such challenges in the future.

¹⁵ BCC Research. Global Markets for Precision Farming. December 2019.

¹⁶ Jessi Devenyns. "Tyson looks to robotics for the future of meatpacking." August 2009. <https://www.fooddive.com/news/tyson-looks-to-robotics-for-the-future-of-meatpacking/560599/>.

Recent Innovation Performance: Ag Equipment, Technologies, and Systems

Research and Innovation Output (2015–2019)	
Research Publications	<p>Total Publications: 110</p> <p>Key Disciplines: Agricultural Engineering, Food Science Technology, Agronomy, and Multidisciplinary Agriculture.</p> <p>Key Corporate Research: None identified through publications.</p>
Patents	<p>Patents Assigned to Indiana Companies: 118 Patents Assigned to Indiana Inventors: 154</p> <p>Key Corporate Assignees:</p> <p>ABI Attachments—13 in this Platform Corteva (including Dow AgroSciences and DuPont Pioneer)—8 in this Platform; 798 Total Earthway Products—4 in this Platform</p>
Innovation Resources and Capital (2015–2019)	
USDA-Funded Research (non-SBIR)	<p>Purdue University—14 Awards—\$7,295,393 University of Notre Dame—1 Awards—\$464,340 State Total—15 Awards—\$7,759,733</p>
SBIR Awards	<p>Two Awards</p> <p>Trellis Growing Systems 2018 Phase II—\$468,818 <i>Low Trellis Production, Harvesting System and Marketing Tools for Locally-Grown Hops and Value-Added Products</i> 2016 Phase I—\$99,961 <i>Low Trellis Production and Harvesting System for Hops</i></p>
Other Federal Tech Development Awards	<p>One Award GRYFN 2015 ARPA-E--\$2,250,000 (sub from Purdue)</p>
Angel & Venture Capital	<p>Summary Companies—12 Deals—21 Investment—\$6.47 million</p> <p>By Deal Type Pre-Seed—7 Deals—\$240,000 Angel—1 Deal—\$230,000 Seed—4 Deals—\$1.31 million Early Stage—7 Deals—\$640,000 Later Stage—2 Deals—\$4.05 million</p>

Source: TEconomy Partners, LLC.

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.
Advanced Agrilytics	Advanced Agrilytics is an agronomic technology company that provides farmers with actionable, customized strategies to deliver sustainable outcomes at the sub-acre level. This hands-on approach combines field-specific data with agronomic research to meet growers at the cross-section of technology.
Applegate Livestock Equipment Inc.	Applegate Livestock Equipment Inc. manufactures fabrication equipment. The company offers gates, corral panels, feeders, stock tanks, feed trains, and cattle-handling equipment.
Banjo Corporation	Banjo Corporation is a manufacturer of liquid-handling products that service agriculture and industrial applications.
Boden BOLT	Boden BOLT is a Purdue start-up that has developed a new way to manage nitrogen using electrical stabilization. BOLT uses a custom double coulter to pass an electric arc through the soil during the application of nitrogen.
Brinly-Hardy Company	Brinly-Hardy designs, builds, and distributes lawn and garden tractor and all-terrain vehicle/utility task vehicle (ATV/UTV) attachments and equipment.
Clear Creek & Associates Inc.	Clear Creek & Associates is a structural, agricultural, and facility engineering company specializing in custom agricultural- and bulk-processing facilities.
Constant Canopy	Constant Canopy brings together innovation from agriculture, energy, and technology to create products to feed, power, and sustain finite natural resources. Solutions include a cropping system that uses relay cropping, where the second crop is planted into the first crop before harvest, rather than waiting until after harvest. Constant Canopy is also focused on turning manure and bio waste into clean fuels.
Cornelius Manufacturing Inc.	Cornelius is the world's leading supplier of beverage-dispensing and -cooling equipment.
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.
Cummins	Cummins is a multinational corporation that designs, manufactures, and distributes engines, filtration, and power generation products.
DTN (fka Spensa Technologies)	DTN provides analysis and decision-support solutions to help growers better manage agronomic pests such as insects, weeds, and disease. The company gathers high-resolution data, then models that data to reveal insights to help agriculturalists make the most informed decisions possible.
EarthWay Products	EarthWay develops and manufactures high-quality lawn, garden, and ice removal tools. EarthWay holds a number of patents on the application of liquid and dry

Company Name	Innovation Area Descriptions
	fertilizers and chemicals to limit fertilizer application next to sidewalks and expensive plantings.
Eco-Tek	Eco-Tek runs manure through a biological process that ultimately turns it into natural bedding for dairy farmers and potting mix for horticulture operations.
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 deicers and heated products to solve the problem of frozen water for animals during the winter.
GeoSilos	GeoSilos supports business, economics, policy, communications, and outreach analysis built upon the foundation of geography and spatial analysis.
GRYFN	GRYFN, a Purdue start-up, offers precise geomatics solutions for co-aligned and repeatable multisensor UAV data collection for research and commercial applications. Its core vertical application empowers plant breeders in major commodity crops with precise, repeatable data and analytic solutions for high-throughput phenotyping in the field.
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.
Honeyville Metal Inc.	Honeyville Metal Inc. designs and fabricates innovative dust collection and grain-handling equipment.
Iotron	Iotron produces electron beam radiation systems for varied applications including food irradiation.
J&H Consulting	J&H Consulting is a developer of an agricultural software intended to forecast yields and improve crop management. The company's agricultural software use digital data sources to improve crop yield forecasting, nutrient management, and environmental protection.
Kasco Manufacturing Co. Inc.	Kasco Manufacturing designs, manufactures, and markets innovative equipment in the landscape, skid steer, and agricultural fields including augers, drills/seeder, harrows, hitches, and seeders.
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.
LeafSpec	LeafSpec, a Purdue start-up, is developing a portable and low-cost hyperspectral imaging handheld device (LeafSpec) providing a digital lab solution for growers to identify in real time the nutrient and chemical compositions of plants.
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.

Company Name	Innovation Area Descriptions
MyFarms	MyFarms develops software that simplifies and automates sustainability to meet the needs of users up and down the food value chain. The software tools make it easier for farmers, ag retailers, grain processors, and consumer brand companies to drive smarter farming decisions based on sustainability insights.
Peakey Enterprise LLC	Peakey Enterprise is a software development company specializing in cloud services, mobile apps, web development, machine learning/AI, and software development services for precision agriculture.
Phicrobe	Using technology developed at Purdue, Phicrobe has created a rapid, simple and inexpensive test for the detection of <i>E. coli</i> O157:H7 based on genetically modified viruses (bacteriophage) that produce light in the presence of the target pathogen without requiring specialized equipment or expensive reagents.
Plan Bee	Plan Bee has created an autonomous pollination device that allows growers to have more control over their crop by providing the ability to work through the night, windy conditions, and cold temperatures when bees cannot.
Progeny Drone Inc.	Progeny Drone Inc., a Purdue-affiliated start-up, has created software that rapidly converts aerial crop photos into useful information for plant breeding, crop modeling, and precision agriculture.
Qmira	Qmira had developed AI to identify, diagnose, and intervene in crop infections. Through this technology, farmers and others in the agricultural sector have a point of product intervention to combat crop infections by scanning the soil, diagnosing undetected parasites and diseases, and treating with the right intervention.
Rabbit Tractors	Rabbit Tractors is building swarm-enabled, autonomous tractors that are approximately one-third the size and one-fourth the weight of normal tractors and spray rigs and capable of pulling implements as well as late-season spraying.
Raven Industries (fka AgSync)	Raven Industries Inc. is a manufacturer of precision agriculture products, high-altitude balloons, plastic film and sheeting, and radar systems.
Riley Equipment Inc.	Riley Equipment designs and manufactures processing machinery and bulk material-handling equipment for grain, fertilizer, seed, feed, and aggregate and mining and a wide variety of industrial markets.
Ring-Co	Ring-Co delivers intentional innovation through digital, mobile, transit, and consulting products and services.
Rogo Ag	Rogo Ag builds and operates autonomous robots to help farmers get more consistent soil samples to ultimately apply their fertilizer more efficiently.
Shambaugh & Son LP	Shambaugh & Son LP is the largest building services engineering construction services contractor in Indiana and ranked the third-largest specialty contractor in the United States. The company specializes in a full range of new and retrofit construction for food processing, biofuel, and other industrial projects.
Soil-Max Inc.	Soil-Max is a manufacturer of gold digger tile plow and agricultural drainage products for tiling needs.

Company Name	Innovation Area Descriptions
Solinftec	Solinftec, a digital precision agriculture company, develops and produces equipment, technology, and systems for the automation of mobile assets and logistics processes.
The Bee Corp	The Bee Corp, an agtech start-up, is focused on solutions for commercial pollination by developing technologies to help growers measure the strength of their bee colonies.
Total Control Systems	Total Control Systems (TCS) is a leading global provider of electronic registration and piston and rotary flow meter solutions for refined fuels, oils, chemicals, LPG, and agriculture applications.
Trellis Growing Systems LLC	Trellis Growing Systems LLC is the inventor/developer of a rotating/multiposition trellis system and has created a line of products specifically designed to increase crop yields and fruit quality of berries and other high-value crops. In 2019, Trellis Growing Systems aligned with Biodyne USA on a joint venture to develop systems for small- to medium-sized private horticulture. It first launched the IBEX Hops Growing System, followed by individual kit systems for individuals for the popular RCA™ and AV™ berry trellis systems.
VAST Power Systems Inc.	VAST Power Systems Inc. (VAST) produces an external combustor that uses water or some other inert thermal diluent rather than air to cool combustion. This technology has allowed the demonstration (through computer simulations and empirical lab testing) of a number of significant benefits.
VinSense	VinSense produces an innovative decision support software system for agricultural crop production. The technology enables producers, field managers, and winemakers to make better crop management decisions to improve production volume, uniformity, and quality and increase profitability and long-term sustainability.
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.

Animal Health and Nutrition

What Does This Sector Do?

The animal health and nutrition sector provides basic and 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 21 establishments identified as being involved in animal health and nutrition with an employment base of 1,674. Example firms include ADM, Cook Animal Health; Elanco, United Animal Health, Micronutrients, and Whiteshire Hamroc.

As of October 2020, the world's human population stood at 7.8 billion.¹⁷ Population projections by the United Nations suggest that, by 2030, the global population will rise to 8.6 billion; and, by 2050, it may reach 9.8 billion.¹⁸ The phenomenon of rising population levels, now combined with rising global incomes, leads to a substantial increase in the demand for animal-derived foods because, as the World Health Organization (WHO) notes, "there is a strong positive relationship between the level of income and the consumption of animal protein."¹⁹ Meeting the increasing demand for high-value animal protein (from meat, milk, and eggs) and associated food products is no small task. In recent years, the world's livestock sector has experienced unprecedented growth, to an extent that WHO reports that "annual meat production is projected to increase from 218 million tonnes in 1997–1999 to 376 million tonnes by 2030." What these projections illustrate is that, while population may increase 10.8 percent by 2030 over current levels, demand for animal-based food products is likely to experience a rate of growth several times higher.

Increasing production of food above current levels and meeting the large-scale demand increases projected for livestock products are major challenges. Good agricultural land is already in production worldwide; and pressing other, more fragile, and marginal lands into production to produce livestock feed and graze livestock degrades the environment and the valuable ecosystem services and biodiversity provided by natural non-cultivated land. As a result, the challenge for those in agbioscience and animal agriculture is to achieve increases in livestock production outputs sufficient to meet large-scale demand increase without significantly increasing the land footprint used in production.

As noted in the previous report for AgriNovus Indiana, innovations in livestock productivity come through three primary channels:

- **Breeding and genetic improvement of livestock**—This area uses both traditional breeding and modern molecular genetics techniques to identify livestock with enhanced productivity traits.
- **Enhanced nutrition and feed products**—This area meets the energy, protein, mineral, and vitamin needs of ruminant and nonruminant livestock via advanced feed and nutritional supplements. Advanced knowledge of livestock digestion, gut microbiome, and other factors are helping advance the development of customized feed and nutrition supplement regimens.

¹⁷ [https://www.worldometers.info/world-population/#:~:text=7.8%20Billion%20\(2020\),currently%20living\)%20of%20the%20world](https://www.worldometers.info/world-population/#:~:text=7.8%20Billion%20(2020),currently%20living)%20of%20the%20world).

¹⁸ United Nations. *World Population Forecast (2020-2050)*. UN Department of Economic and Social Affairs, Population Division. *World Population Prospects: The 2017 Revision*. (Medium-fertility variant). Reported at: <https://www.worldometers.info/world-population/>.

¹⁹ WHO. "Global and regional food consumption patterns and trends—availability and changes in consumption of animal products." Accessed online at: https://www.who.int/nutrition/topics/3_foodconsumption/en/index4.html.

- **Animal health and 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. Significant innovation activity is required in animal health to offset reductions in the use of prophylactic antibiotics (with vaccines, immunotherapeutics, and digital health surveillance approaches being developed as alternatives).

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

The International Feed Industry Federation places the size of the global commercial feed production industry at \$400 billion, up 8.1 percent from the \$370 billion in 2014.²⁰ A September 2020 report by BCC Research places the global market for feed being higher, at \$483.6 billion for 2020 and anticipates the market growing to \$606.8 billion by 2025 (a CAGR of 4.6 percent for 2020–2025).²¹ The U.S. feed market is estimated by BCC Research at \$104 billion for 2020, growing to \$132.4 billion in 2025 (a 2020–2025 CAGR of 4.9 percent).

Agbioscience is contributing not only to enhancing productivity in feed production through plant science and agronomic advancements, but also in the development of feed supplements designed to improve the health and performance of the animal. Feed supplement products are diverse and comprise vitamins, amino acids, antibiotics, antioxidants, enzymes, and other nutritional supplement elements added to livestock feed to improve animal health and performance. BCC Research estimates that the North American market for feed supplement products is \$16.7 billion in 2020, anticipated to grow to \$20.5 billion by 2025 (a CAGR of 4.2 percent).

As noted above, animal health and veterinary medicine products also make up a dynamic sector of the market. BCC Research estimates that the global animal therapeutics and diagnostics market should grow from \$49.9 billion in 2019 to \$66.5 billion by 2024 with a CAGR of 5.9 percent.²² The anticipated breakout in terms of therapeutics and diagnostics are as follows:

- The global animal therapeutics (or pharmaceuticals) market should grow from \$19.9 billion in 2019 to \$26.9 billion by 2024 with a CAGR of 6.2 percent for the period of 2019–2024.
- The global animal diagnostic products market should grow from \$4.0 billion in 2019 to \$5.8 billion by 2024 with a CAGR of 7.9 percent for the period of 2019–2024.

BCC Research also includes feed additives in its definition of the sector. If additives are removed, and only its estimates for pharmaceuticals/therapeutics, vaccines, and diagnostics are considered, the market projections are as follows:²³

²⁰ <http://www.ifif.org/pages/t/The+global+feed+industry>.

²¹ BCC Research. *Compound Feeds and Additives: Global Markets*. September 2020.

²² BCC Research. *Global Markets for Animal Therapeutics and Diagnostics*. March 2020.

²³ Ibid.

Table 14: Global Market for Animal Therapeutics and Diagnostics, by Product Type, Through 2024 (\$M)

Product Type	2018	2019	2024	CAGR% 2019–2024
Pharmaceuticals/therapeutics	19,080	19,910	26,920	6.2
Vaccines	7,415	7,800	10,465	6.1
Diagnostics	3,665	3,960	5,795	7.9

Source: BCC Research.

Overall, it is clear that global demographic and wealth trends are favorable for continued growth and development in the animal health and nutrition sector. Indiana continues to be 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.

Recent Innovation Performance: Animal Health and Nutrition

Research and Innovation Output (2015–2019)	
Research Publications	<p>Total Publications: 887</p> <p>Key Disciplines: Agriculture, Dairy & Animal Science, Veterinary Sciences, and Infectious Diseases</p> <p>Key Corporate Research: Elanco—94 publications in this Platform. United Animal Health—15 publications in this Platform. ADM (Illinois)—6 publications in this Platform.</p>
Patents	<p>Patents Assigned to Indiana Companies: 106 Patents Assigned to Indiana Inventors: 109</p> <p>Key Corporate Assignees: Elanco Animal Health—9 Total Patents Corteva (including Dow AgroSciences and DuPont Pioneer)—10 in this Platform; 798 Total</p>

Innovation Resources and Capital (2015–2019)	
USDA-Funded Research (non-SBIR)	Purdue University —4 Awards—\$1,330,774 Indiana University —1 Award—\$161,936 State Total —5 Awards—\$1,492,710
SBIR Awards	One Award NutraMaize LLC 2017 Phase I—\$99,977 <i>High Carotenoid Orange Corn for Poultry Health</i>
Angel & Venture Capital	Summary Companies—4 Deals—4 Investment—\$1.34 million By Deal Type Pre-Seed—1 Deal—\$100,000 Seed—2 Deals—\$40,000 Early Stage—1 Deals—\$1.20 million

Companies that are Actively Involved with this Innovation Sector

Company Name	Innovation Area Descriptions
Archer-Daniels-Midland Company	The Archer-Daniels-Midland Company, commonly known as ADM, is a multinational food-processing and commodities-trading corporation operating facilities where cereal grains and oilseeds are processed into products used in food, beverage, nutraceutical, industrial, and animal feed markets worldwide.
Agri Processing Services LLC	The Agri Processing Services LLC, or APS, is a manufacturer, distributor, and marketer of PFC™, a specialty processing and wastewater treatment compound, designed specifically for the food-processing industry.
Belstra Milling	Belstra Milling is a manufacturer of feed for a variety of animals and supplier of agricultural products.
Cargill (Animal Nutrition)	Some of Cargill's major businesses are trading, purchasing, and distributing grain and other agricultural commodities, such as palm oil; the raising of livestock and production of feed; and producing food ingredients such as starch and glucose syrup and vegetable oils and fats for application in processed foods and industrial use.
Cook Animal Health	Cook Animal Health is a veterinary pharmaceuticals and health products company formed by Cook Biotech.
E-Collar Technologies Inc.	E-Collar Technologies is a premier provider of dog training collars, bark collars, remote training collars, and dog training equipment.
Elanco Animal Health Inc.	Elanco Animal Health is a global animal health, protein, and food-production safety company, producing medicines and vaccinations for pets and livestock.

Company Name	Innovation Area Descriptions
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.
Owl Manor Medical	Owl Manor Medical is a privately held medical device company dedicated to companion-animal joint and soft tissue preservation through advanced lameness technologies.
Sauder Feeds	Sauder Feeds manufactures a wide variety of animal feeds and custom-formulated feeds, as well as animal nutrition, health, and equipment products.
Synergy Feeds LLC	Synergy Feeds provides full nutrition and consulting services to swine and dairy businesses throughout Northeast Indiana and Central Michigan. Synergy Feeds is a 50/50 partnership between Ag Plus and Ceres Solutions.
Teichos Laboratories	Teichos Laboratories is the developer of immunotherapy intended for bovine mastitis. The company's technology uses synthetic versions of the bacterial cell wall, enabling clients to direct the immune response mechanism.
Tyson Foods (Tyson Feed)	Tyson Foods is a modern, multinational, protein-focused food company producing approximately 20 percent of the beef, pork, and chicken in the United States. To help ensure that no part of the chicken goes to waste as a means to improve environmental sustainability, Tyson Ingredient Solutions produce 100 percent chicken-based ingredients for animal feed, pet food, and aquaculture feed.
United Animal Health	United Animal Health provides proven, research-based nutrition and health solutions that create value for livestock producers.
Whiteshire Hamroc	Whiteshire Hamroc is a swine-breeding and genetics company that also produces an innovative building and ventilation system for swine breeding.
ZeaVaxx LLC	ZeaVaxx LLC is an animal healthcare company that is dedicated to improving current animal vaccines through a plant-derived nanoparticle adjuvant platform.

Chapter V. Measuring the Economic Performance of Indiana's Agbioscience Innovation Platforms

The purpose of this chapter is to examine the economic progress of Indiana's agbioscience platforms and establish a benchmark upon which to assess future economic progress and the efforts of AgriNovus Indiana. To measure this progress requires a combination and extension of previous metrics around industry employment and innovative firm employment to be able to estimate and capture these economic results.

Platform Employment Data Used for Impact Analysis

This analysis begins by assessing the entire Indiana agbioscience industry and mapping it into one of the four innovation platforms (based on industry NAICS codes), and an additional fifth platform, representing actual agricultural production and distribution activities. Additionally, these five platforms are mapped, as appropriate due to their component NAICS codes, into the various sectors represented within an IMPLAN model of the state of Indiana. The purpose of this work is to show the relative importance, performance, and economic impact of each of the platforms (now representing the entire Indiana agbioscience landscape from research to product and from production to processing).

Unlike the earlier Chapter II analysis where the BEA Farm Proprietor data are included as a single data point within the Primary Production segment, the need to develop an IMPLAN model to evaluate the economic impact of the agbioscience platforms requires a slightly different data approach. The IMPLAN model includes state-level estimates, developed using BEA and USDA data, of the Farm Proprietor-based employment included within each of the different crop and livestock production sectors. Additionally, a few other sectors related to the agbiosciences within the IMPLAN model include estimations for proprietors (non-Farm Proprietors) as well.

Importantly, this analysis also includes the employment from specific Indiana innovative agbioscience firms that are part of the state's comprehensive agbioscience landscape based on their products or services, but fall into NAICS codes not directly tied to, and hence outside of, the agbioscience industry definition used in the Chapter II analysis. For example, a company making plastic items used in farm operations classified as NAICS 326199—All Other Plastics Product Manufacturing is not included in the Chapter II analysis. Similarly, firms classified within NAICS 541511—Custom Computer Programming Services, that are developing agbioscience applications, are also not included in the Chapter II analysis, since the vast majority of that NAICS code is unrelated to the agbiosciences.

Due to these important considerations and inclusions, the “total” employment figures represented in this Chapter VI analysis are somewhat larger and not completely comparable with the total Indiana agbioscience employment figures provided in the Chapter II analysis.

Indiana's Agbioscience Platform Employment

Agbioscience employment in Indiana, as represented by the five platforms in this analysis, exceeded 146,000 workers (and proprietors) in 2018 and grew by 5.4 percent since 2012. Though recent growth slowed in comparison with the 2012–2015 period, it nonetheless stayed positive in the recent 2015–2018 period. However, the overall growth of the agbioscience employment in Indiana lagged overall

private sector growth, which grew by 10.1 percent from 2012–2018, including a growth rate of 4.8 percent from the recent 2015–2018 period.

Similar to the Chapter II analysis, Agricultural Production and Distribution employs the largest number of Indiana workers and proprietors with nearly 70,000 employed in this platform (Table 15). Important for Indiana, is the fact that even with the structural changes of the modern U.S. agriculture industry this agricultural production and distribution employment has stayed remarkably stable since 2012 and accounts for 47.5 percent of the state’s agbioscience employment (Figure 19).

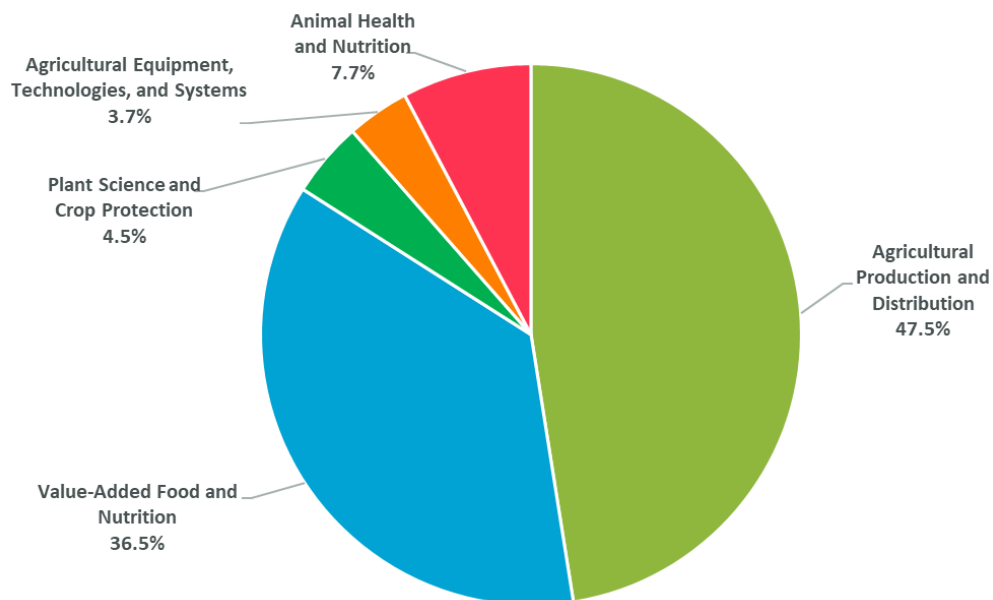
Table 15: Employment and Employment Growth of Indiana’s Agbioscience Platforms (2012–2018)

Innovation Platform	Employment			% Employment Change		
	2012	2015	2018	2012–2015	2015–2018	2012–2018
Agricultural Production and Distribution	69,457	70,357	69,431	1.3%	-1.3%	0.0%
Value-Added Food and Nutrition	46,737	50,611	53,393	8.3%	5.5%	14.2%
Plant Science and Crop Protection	7,799	7,548	6,584	-3.2%	-12.8%	-15.6%
Agricultural Equipment, Technologies, and Systems	5,189	5,756	5,474	10.9%	-4.9%	5.5%
Animal Health and Nutrition	9,531	10,030	11,305	5.2%	12.7%	18.6%
Total Indiana Agbioscience	138,713	144,302	146,187	4.0%	1.3%	5.4%

Source: TEconomy analysis.

The Value-Added Food and Nutrition platform accounts for the second-largest level of employment among the five platforms, representing the size and diversity of food product manufacturing occurring within the state. This platform accounts for more than 53,000 employees (36.5 percent of Indiana agbioscience employment, as shown in Figure 19) and continues to be a growth engine for the state, with employment increasing by more than 14 percent since 2012.

Figure 19: Agbioscience Platform Shares of Indiana Total Agbioscience Employment (2018)



Source: TEconomy analysis.

At more than 6,500 employees, the Plant Science and Crop Protection platform, the single most innovative of the platforms based upon the number of related patents and research publications, is also showing the largest decline in employment, losing 15.6 percent of its employment over the 2012–2018 period, while accounting for 4.5 percent of Indiana’s total agbioscience employment. Though this analysis improves upon the employment “accounting” of some corporate restructuring and related NAICS code changes (e.g., better capturing Corteva’s 2018 Indiana employment) occurring among key platform companies, larger firms across this platform (e.g., Corteva, Bayer) are still subject to downsizing, transferring of key functions to other locations, mergers and acquisitions (M&A) activities, and other downward pressures on employment levels.

The Agricultural Equipment, Technologies, and Systems platform is dominated by the distribution of agricultural implements and equipment, accounting for 60 percent of the platform’s employment. From an innovation perspective, this platform also captures key in-state production of agricultural equipment as well as emerging agricultural software, applications, and systems providers, which account for much of the employment growth within this platform. Examination of the employment of the known innovative firms in this platform (identified via patent and/or venture capital activities; employment from Dun & Bradstreet) shows that these innovative firms, in fact, have grown over the 2015–2018 period by more than 28 percent (over 600 jobs). This indicates that the non-innovative remainder of this platform, primarily within the distribution aspects, is declining at a significant rate.

Finally, the Animal Health and Nutrition platform accounts for over 11,000 jobs and represents 7.7 percent of Indiana agbioscience employment. While it is unique with the inclusion of Elanco’s Indiana operations, it is dominated by the broadly defined Veterinary Services component that includes both livestock and companion animal services and accounts for 72 percent of the platform’s employment. While some of the platform’s employment growth is attributable to growth in animal feed and health products, much of the growth is occurring within this Veterinary Services component—with

employment increasing by over 1,400 jobs from 2012–2018, helping it account for the highest rate of growth of any platform from 2012–2020.

Output and Economic Impacts of Indiana’s Agbioscience Platforms

To assess the economic performance and impact of the Indiana agbioscience platforms, IMPLAN input/output analysis was used (for more information on input/output analysis and the measures derived from the IMPLAN model, see “**Overview of Input/Output Analysis**” text box). For the overall analysis, a single model was developed representing the activities (as measured by employment) for the five platforms for the years 2012, 2015, and 2018. TEconomy decided to use the IMPLAN Indiana 2018 model for all three periods due to the significant improvements of the 2018 models over previous years in how the wholesale components are represented (prior to the 2018 models, all wholesale activities were combined into a single IMPLAN sector; now they are divided into 10 sectors and reflect the underlying differences in the NAICS codes).

While subtle changes may exist in the production functions for these components over the individual years, inflationary adjustments at the individual sector level should account for the most significant variability in output value due to different market prices in each of the years. For each year, the model was run using current year dollars (e.g., 2012 modeled with 2012 dollars), with results estimated in both current year dollars and in 2018 dollars for comparability.

Table 16 shows the output estimated by the IMPLAN model for all three periods in 2018 dollars to better understand the real (versus inflationary) change over time. Among the five Indiana platforms, four platforms exhibited “real” output growth over the 2012–2018 period, with three showing real output growth in the more recent 2015–2018 period.

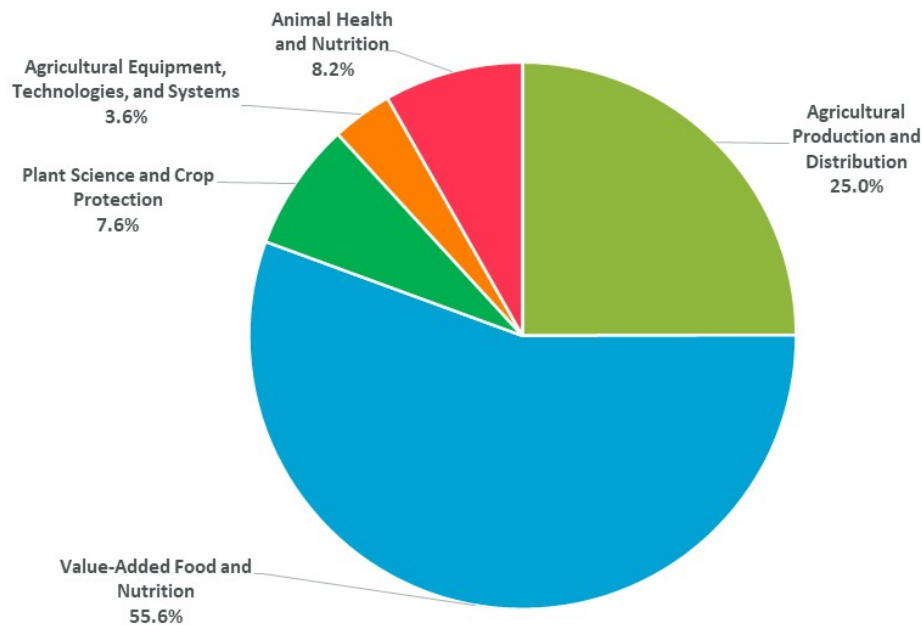
Table 16: Estimated Output and Real Change in Output of Indiana’s Agbioscience Platforms (2012–2018)

Innovation Platform	Output (in 2018 dollars; \$M)			% Real Output Change		
	2012	2015	2018	2012–2015	2015–2018	2012–2018
Agricultural Production and Distribution	\$12,547.1	\$12,230.8	\$13,051.0	-2.5%	6.7%	4.0%
Value-Added Food and Nutrition	\$25,758.0	\$28,231.8	\$29,103.4	9.6%	3.1%	13.0%
Plant Science and Crop Protection	\$5,441.3	\$5,436.5	\$3,979.0	-0.1%	-26.8%	-26.9%
Agricultural Equipment, Technologies, and Systems	\$1,618.9	\$2,021.3	\$1,872.2	24.9%	-7.4%	15.6%
Animal Health and Nutrition	\$3,960.5	\$4,036.7	\$4,301.2	1.9%	6.6%	8.6%
Total Indiana Agbioscience Industry	\$49,325.7	\$51,957.1	\$52,306.8	5.3%	0.7%	6.0%

Source: TEconomy analysis using IMPLAN 2018 State of Indiana model. Note: columns may not sum due to rounding.

The size and “closer to final demand” nature of the Value-Added Food and Nutrition platform is demonstrated by its significant \$29.1 billion output figure for 2018—accounting for 56 percent of the total Indiana agbioscience sales (Figure 20). Additionally, the significant value of the farmgate proceeds from Agricultural Production and Distribution within the state yields annual output of over \$13 billion in 2018.²⁴

Figure 20: Agbioscience Platform Shares of Indiana Total Agbioscience Output (2018)



Source: TEconomy analysis using IMPLAN 2018 State of Indiana model.

Though the smallest in overall output, the Agricultural Equipment, Technologies, and Systems platform achieved the largest output growth rate over the full 2012–2018 period, 15.6 percent, even considering a decline of 7.4 percent from 2015 to 2018. This estimated real decline reflects both the innovative context of this platform discussed above, with innovative firms actually expanding over this period, and the addition of firms engaged in agricultural software, systems, and other aspects of “precision agriculture.” However, contraction of non-innovative firms in this platform are offsetting such innovative-based increases in output.

Though representing only 8.2 percent of the total agbioscience economic output, continued and accelerating real growth is shown within the Animal Health and Nutrition platform over the full 2012–2018 period.

The Plant Science and Crop Protection platform’s output results, declining by 26.8 percent from 2015 to 2018, are likely affected by and reflect a combination of stand-alone research and administrative operations that can show lower output levels as “sales” are captured elsewhere within the corporate

²⁴ Readers are reminded that this value consists only of the crop and livestock aspects of “agriculture.” This analysis does not include forestry output. Additionally, the employment of a small number of firms, due to their “innovative” nature and customer facing production, were moved from the Agricultural Production and Distribution platform to the Value-Added Food and Nutrition platform.

structures. For example, the evolving landscape in Indiana with both Corteva corporate activities and the Bayer acquisition of Monsanto may change the way output data are reported and captured within the state.

Overview of Input/Output Analysis

Input/output (I/O) analysis models the interrelationships and financial transactions between economic sectors. I/O multipliers are based on the flow of commodities between industries, consumers, and institutions in a state or regional economy. The analysis uses an Indiana state-specific I/O model developed by IMPLAN. The IMPLAN model, used by TEconomy, is the most widely deployed model in the nation and is based on the U.S. Bureau of Economic Analysis (BEA) national accounts data, supplemented with state-level employment data from the U.S. Bureau of Labor Statistics (BLS) and other economic data from BEA, the U.S. Bureau of the Census, and other federal agencies. The resulting analysis calculates three types of effects or impacts:

- **Direct Effect**—the specific impact of the direct expenditures of the agbioscience industry companies
- **Indirect Effect**—the impact of national or in-state suppliers to these companies
- **Induced Effect**—the additional economic impact of the spending of employees and suppliers' employees
- **Total Impact** = the sum of the three effects combined.

The I/O analysis effectively models multiplier effects (also known as “ripple effects”) that originate from agbioscience company expenditures in the United States and individual state economies.

The IMPLAN I/O model is used to derive estimates for five impact metrics:

- **Output** (also known as production, sales, or business volume) is the total value of the goods and services produced in the economy.
- **Employment** is the total number of jobs supported and includes the direct employment at industry operations.
- **Labor Income** is the total amount of income, including salaries, wages, and benefits (including both social security and unemployment insurance), received by employees, owners, and others in the related supply chain.
- **Value-Added** is the contribution to growth in gross domestic product (GDP).
- **Government Revenues** includes estimates of revenues generated for state/local and federal governments through the economic activity measured. *It should be noted that government revenue metrics do not include “multiplier” calculations.*

While the input/output models allow for an estimation and examination of platform-specific output, the overall economic value or impact to the state of each platform, and ultimately the entire Indiana agbioscience industry, can also be assessed.

The full impact analysis of the Indiana Agricultural Production and Distribution platform (Table 17) reveals a total economic impact of nearly \$20 billion when capturing the direct platforms output; sales of in-state suppliers; and Indiana workers, including farm proprietors, spending their wages on personal consumption.²⁵

²⁵ It should be noted that when economic research reports discuss the “total impact” of a project, firm, or industry, they are typically referring to the total output impacts.

Table 17: Economic Impact of Indiana’s Agricultural Production and Distribution Platform (2018)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	State/Local Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	69,431	\$1,715.65	\$3,743.54	\$13,051.00	\$174.51	\$300.22
Indirect Effect	21,766	\$1,379.10	\$2,241.80	\$4,430.31	\$203.15	\$254.14
Induced Effect	17,820	\$851.92	\$1,444.57	\$2,512.23	\$133.77	\$170.56
Total Impact	109,016	\$3,946.67	\$7,429.90	\$19,993.53	\$511.43	\$724.92
Multiplier	1.57	2.30	1.98	1.53		

Source: TEconomy analysis using IMPLAN 2018 State of Indiana model.

This performance yields an output multiplier of 1.53—in other words, every \$1 of output generated by the platform’s firms (e.g., individual farmers, corporate farms, and ag commodity distribution facilities) also generates an additional \$0.53 within Indiana’s economy. Similarly, these economic activities connected to the more than 69,000 direct platform workers supports an additional 39,586 workers throughout Indiana.

Examining the impacts of the state’s Value-Added Food and Nutrition Platform (Table 18) reveals a total economic impact of more than \$41 billion in 2018 while supporting the employment of nearly 126,000 Indiana workers. Importantly, this platform, including its supply chain and workers, returns nearly \$990 million to the state in the form of state and local tax revenues, while generating more than \$1.5 billion in federal tax revenues.

Table 18: Economic Impact of Indiana’s Value-Added Food and Nutrition Platform (2018)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	State/Local Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	53,393	\$3,277.06	\$7,176.13	\$29,103.40	\$439.20	\$715.66
Indirect Effect	39,298	\$2,501.45	\$3,662.84	\$7,245.87	\$293.89	\$481.10
Induced Effect	33,081	\$1,582.90	\$2,686.72	\$4,670.77	\$249.13	\$316.96
Total Impact	125,772	\$7,361.41	\$13,525.70	\$41,020.04	\$982.22	\$1,513.72
Multiplier	2.36	2.25	1.88	1.41		

Source: TEconomy analysis using IMPLAN 2018 State of Indiana model.

The impact analysis of the Plant Science and Crop Protection platform (Table 19) estimates total output impacts of more than \$6 billion in 2018. The unique operations within the Indiana firms in this platform, combining research, product development, production, and administrative activities, is represented by the fact that, unlike the other four platforms, this platform generates more employment in its Indiana-based supply chain (Indirect Effect) than are employed by the actual firms in the platform. This platform also is characterized by the largest employment multiplier of any platform at 2.92—for every direct job in this platform, nearly two additional jobs (1.92) are supported within the state of Indiana.

Table 19: Economic Impact of Indiana’s Plant Science and Crop Protection Platform (2018)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	State/Local Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	6,584	\$562.39	\$1,581.71	\$3,978.97	\$141.18	\$136.84
Indirect Effect	6,934	\$428.78	\$642.27	\$1,231.78	\$52.13	\$82.22
Induced Effect	5,676	\$271.57	\$460.92	\$801.31	\$42.74	\$54.38
Total Impact	19,194	\$1,262.74	\$2,684.90	\$6,012.06	\$236.04	\$273.44
Multiplier	2.92	2.25	1.70	1.51		

Source: TEconomy analysis using IMPLAN 2018 State of Indiana model.

Though the smallest of the five platforms in terms of total economic impact, the Agricultural Equipment, Technologies, and Systems platform (Table 20) generates a total economic (output) impact of nearly \$3.1 billion. The “manufactured product” aspect of this platform, however, generates an output multiplier of 1.65—the largest among the five agbioscience platforms as firms within this platform are most likely to buy manufactured and pre-assembled components. This platform also has a substantial employment multiplier of 2.41, stemming from the total employment impacts of more than 13,000 supported jobs.

Table 20: Economic Impact of Indiana’s Agricultural Equipment, Technologies, and Systems Platform (2018)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	State/Local Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	5,474	\$452.91	\$764.79	\$1,872.21	\$43.44	\$91.87
Indirect Effect	3,812	\$232.22	\$339.04	\$668.93	\$23.20	\$43.95
Induced Effect	3,923	\$187.69	\$318.57	\$553.83	\$29.54	\$37.58
Total Impact	13,209	\$872.82	\$1,422.40	\$3,094.97	\$96.19	\$173.41
Multiplier	2.41	1.93	1.86	1.65		

Source: TEconomy analysis using IMPLAN 2018 State of Indiana model.

The economic impacts of the Animal Health and Nutrition platform (Table 21) are significantly influenced by the substantial veterinary medicine “service” aspect of the platform’s employment. Though the platform is the third-largest among the five in total employment and total output impacts, its services-dominated nature generates the smallest multipliers among the five platforms across all four metrics with multipliers.

Table 21: Economic Impact of Indiana’s Animal Health and Nutrition Platform (2018)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	State/Local Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	11,305	\$656.53	\$1,679.05	\$4,301.18	\$114.54	\$150.30
Indirect Effect	3,928	\$263.14	\$416.20	\$797.82	\$29.60	\$51.07
Induced Effect	5,265	\$251.92	\$427.59	\$743.35	\$39.65	\$50.44
Total Impact	20,498	\$1,171.59	\$2,522.84	\$5,842.35	\$183.78	\$251.81
Multiplier	1.81	1.78	1.50	1.36		

Source: TEconomy analysis using IMPLAN 2018 State of Indiana model.

Taken together, these five platforms (Table 22 and Figure 21), with direct output over more than \$52 billion, combine to generate and support a total economic impact within the state of Indiana of nearly \$76 billion in 2018. The distribution of this total economic impact roughly parallels the distribution of direct output, much more than it does direct employment. In terms of the agbiosciences contribution to the gross state product (GSP) of Indiana, the industry accounts for nearly \$15 billion in direct contribution and ultimately supports over \$27.5 billion in state GDP.

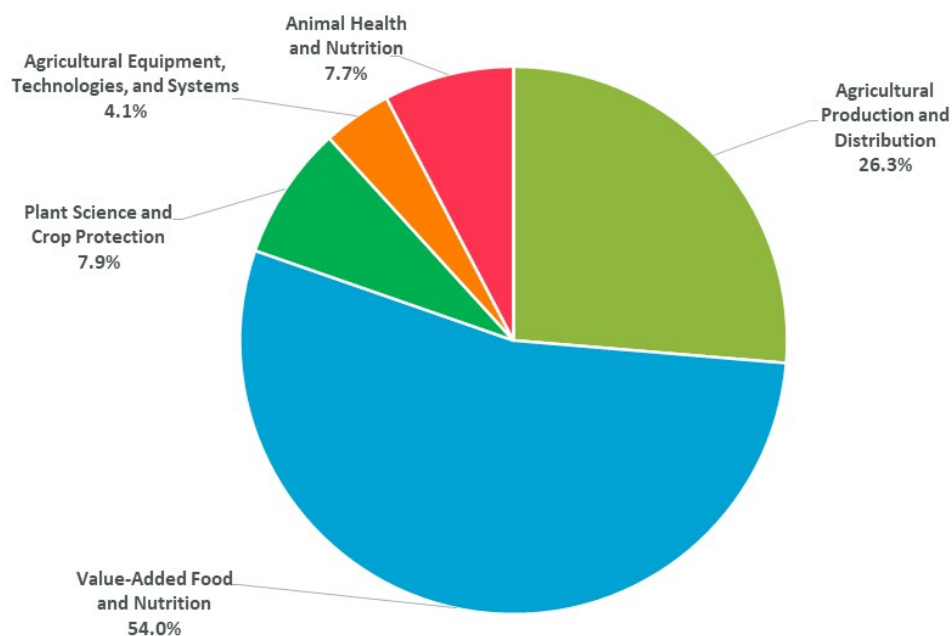
This agbioscience combined economic activity in concert with the combined platforms' employment of 146,187 jobs supports a total of nearly 288,000 jobs in Indiana—nearly a 1-to-1 employment multiplier (for every direct agbioscience job, 0.97 additional jobs are supported in the state. For comparison, Indiana's pharmaceutical preparation industry sector (NAICS 325412) has an employment multiplier of 4.48 and an output multiplier of 1.31.

Table 22: Economic Impact of Indiana's Total Agbioscience Industry (2018)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	State/Local Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	146,187	\$6,664.54	\$14,945.21	\$52,306.75	\$912.87	\$1,394.89
Indirect Effect	75,737	\$4,804.69	\$7,302.15	\$14,374.71	\$601.97	\$912.48
Induced Effect	65,764	\$3,146.00	\$5,338.38	\$9,281.49	\$494.82	\$629.93
Total Impact	287,689	\$14,615.24	\$27,585.73	\$75,962.95	\$2,009.66	\$2,937.29
Multiplier	1.97	2.19	1.85	1.45		

Source: TEconomy analysis using IMPLAN 2018 State of Indiana model.

Figure 21: Agbioscience Platform Shares of Indiana Total Agbioscience Economic Impact (2018)



Source: TEconomy analysis using IMPLAN 2018 State of Indiana model.

Chapter VI. Competing Economic Development Initiatives

Indiana has established a well-deserved reputation as being among the pioneers in standing up a dedicated organization to promote focused agbioscience-based economic development through the efforts of AgriNovus Indiana. Recognizing the power and promise of the sector for advancing economic development in the state, AgriNovus Indiana and its regional and statewide partners are pursuing a series of initiatives and programs designed to enhance awareness of agbioscience opportunities in Indiana, convene stakeholders to advance unique collaborations, promote entrepreneurship and new agbioscience business growth, increase access to capital, and build a science, technology, engineering, and mathematics (STEM) workforce to meet labor demands.

In addition, specific regional efforts being pursued across the state include:

- **Wabash Heartland Innovation Network (WHIN)**—WHIN received a \$40 million grant from the Lilly Endowment in 2018 to help harness the power of Internet-enabled sensors to develop the region into a global epicenter of digital agriculture and next-generation manufacturing. The region's strong commodity base and enterprising agribusinesses help position the region for long-term opportunities to advance the technology-driven agbiosciences.
- **Purdue Foundry**—exists to help Purdue students, faculty, and local alumni move ideas to the marketplace more quickly. It is a place to transform innovators into entrepreneurs by providing advice on entity formation, ideation, market analysis, and business model development.
- **Purdue's Ag-Celerator**—a \$2 million plant sciences innovation fund that provides critical start-up support for Purdue innovators looking to commercialize patented IP or Purdue plant science technologies. As of 2019, Ag-Celerator has funded 12 start-ups and invested \$655,000.
- **Northeast Indiana**—under the leadership of the Northeast Indiana Regional Partnership, the comprehensive food and agriculture cluster strategy that is currently being advanced will focus additional efforts on agbioscience promotion and expansion.
- **Southwest Central Indiana**—under the leadership of Radius Indiana, agribusiness is a targeted industry cluster for which the organization focuses its economic development efforts.
- **Pantheon Business and Innovation Theatre**—Purdue University's Davidson School of Chemical Engineering and the Purdue Research Foundation are investing in an entrepreneurship initiative in Knox County through the support of a recently announced EDA grant. The initiative will help commercialize Purdue's technology with area startups and corporations at the intersection of ag-tech innovation.

Important Elements of Competing Efforts

Today, however, Indiana does not stand alone in terms of its focus on growing an economy based on innovative agbiosciences and the agri-food value chain. Advancements in modern biosciences, digital technologies, advanced analytics, and other fields are converging to create substantial opportunities for innovation, new business development, and business expansion in agbioscience; and other states, regions, and nations have recognized the power and promise of the sector for their economic development.

What has quite rapidly emerged is a growing universe of U.S. and international organizations focused on advancing agri-food and agbioscience innovation commercialization. Organizational types dedicated to accomplishing innovative agricultural and food industry development vary quite considerably, with the following types of structures in evidence:

- Independent nonprofit organizations
- National or state government organizations
- For-profit, investment-focused organizations with links to major venture-capital funds (and sometime, individual multinational corporations)
- Academic-based development organizations.

Dedicated organizations exist that are solely focused on agbioscience and associated development, while there are also significant initiatives directed at agricultural and food industry development operating within broader national, state, or regional technology-based economic development organizations. Most organizations have a specific geographic focus to their work (coming from an economic development tradition), but there are also now organizations that span multiple geographies and international borders. It should also be noted that there is evident variation in how broad or niche-focused organizations may be. Some, like AgriNovus Indiana, are very much focused on the science and tech-heavy agbioscience sector, where advancements in biology, chemistry, food process engineering, and digital/automation convergence are a key emphasis. Others include agbioscience but are also engaged in more general promotion of agricultural development, small farm enterprise development, food product entrepreneurship, and generally advancing further value-added activities with agricultural commodities produced in their location (region, state, or nation).

The types of services and programmatic activities provided by the organizations also show significant diversity. A broad spectrum of functions is provided by organizations as they seek to advance innovative agbioscience and associated industry development, with primary categories including those shown in Table 23.

Table 23: Economic Development Program Areas for Agbioscience and Agri-Food Sector Advancement

Program Area	Typical Activities
Information and resource aggregation	Services designed to provide connectivity for agriculture and food entrepreneurs and new business enterprises to a broad variety of resources, typically provided by other organizations. Designed as a key point of contact for then being directed to suitable resources.
Networking, events, and ecosystem structuring	Initial organization and networking functions designed to convene key stakeholders around the innovative agbioscience sector. Ongoing networking events and virtual connections serving to advance the ecosystem and a sense of shared community.
Farmer/Producer networks for technology piloting, demonstration, and new crops	One of the challenges of developing new agricultural products and technologies is access to farmland for the testing, piloting, and demonstration of technologies. There is a small, but growing, cadre of organizations focused on facilitating this.

R&D advancement and platform development	Activities focused on advancing research activity and access to R&D resources. Includes programs to identify and advance core competencies; identify strengths to build upon; and connect R&D performers in industry, academic, government, and nonprofit institutions.
Entrepreneurship, mentorship, and acceleration	Functions that are focused on developing and supporting entrepreneurs. Includes programs in business plan development, access to advisors and mentors, acceleration services, etc.
Innovation incubator space and shared working space access	Development and/or operation of physical business incubators and accelerator facilities designed to accommodate and support growing agbioscience and agri-food businesses.
Capital access	Services to help access private risk capital or other capital resources and government financing programs. May include organizations that only help connect to external capital or organizations that have their own capital resources to invest.
Education and workforce development	Activities focused toward securing access to the specialized STEM workforce that agriscience and innovative agri-food businesses require. Ranges across the K–12, higher education, continuing education, and job training/retraining spectrum.
Public and government affairs	Activities that seek to promote the sector to government and the public to raise awareness of sector opportunities and needs. Covers areas such as taxes, regulations and the policy environment, public affairs; and promoting investment of government resources in R&D, education, and other key areas.
Regional promotion, inward investment, and trade	Provision of services and research-based information to promote awareness of the geography as a hub for innovative agbioscience and encourage inward investment by companies. Also includes building international trade and collaboration initiatives.

Source: TEconomy Partners, LLC.

During the past decade, and accelerating in the past few years, a substantial number of organizations have become engaged in the provision of some or all of the above program areas. Organizations engaging in the space include:

- **AgLaunch**, headquartered in Memphis, focuses its efforts in Tennessee (as well as select locations across the nation) on attracting, creating, and growing agtech startups, facilitating the development of new agriculture and food value-chains, and building collaborative farmer networks, with a commitment to intentional inclusion.
- **America’s Cultivation Corridor**, headquartered in Ames, Iowa, is a cluster-based economic development organization that focuses its efforts on developing and marketing the agricultural and bioscience economy in Iowa, connecting innovators and leaders around the world through a public-private partnership.
- **Grow North**, headquartered in Minneapolis, is a nonprofit which operates out of the University of Minnesota’s Holmes Center for Entrepreneurship and aims to support and advance food and agriculture startups in Minnesota.
- **The Yield Lab**, headquartered in St. Louis, is an agribusiness accelerator that runs cohorts of agriculture technology companies that, if accepted into the program, receive business

development assistance as well as equity investments. Yield Lab also operates accelerator programs in Ireland, Argentina, and Singapore.

- **Thrive Agtech Accelerator** by SVG Ventures, headquartered in Los Gatos, California, is an accelerator that invests and works with entrepreneurs and investors focused on promising technologies in agriculture and food, whether a seed or growth startup.
- **FOOD-X**, headquartered in New York, is a food innovation accelerator helping food entrepreneurs bring their products and services to market. It is a member of SOSV, the Accelerator VC, a global fund with over \$625M assets under management and a staff of over 100 operating accelerators in a variety of technological areas.
- **Shakeup Factory**, headquartered in Paris, France, is a business accelerator and network catalyst focused on adding value in the growth and transformation of breakthrough projects involved in the farm to fork movement.
- **GROW**, headquartered in Singapore, is a global accelerator backed by Enterprise Singapore, AgFunder, and Dole. It is an agri-food tech accelerator working with companies across Southeast Asia focused on building innovative solutions to industry challenges, such as yield predictions for farmers, food waste reduction in the supply chain, and the production of packaging alternatives.
- **Sweden Foodtech**, located in Stockholm, focuses on delivering innovation programs and business development opportunities to entrepreneurs, providing corporate partners with expertise in open innovation and emerging technologies, assisting partner VCs with their portfolio startups, and promoting the Sweden Foodtech scene at home and abroad through events and conferences.
- **Helsinki Founder Institute FoodTech Programme**, located in Finland, helps launch promising companies in the food-tech space and further establish Helsinki as a center for food innovation. The initiative is designed to accelerate progress for food founders as they pursue technology solutions.

It is evident that there exists a broad spectrum of approaches to promoting agbioscience and associated agtech and foodtech innovation. No single organization has been identified that provides all of the attributes described in Table 23. As can be seen on Table 24, all 11 of the organizations provide two types of services: indirect access to capital (by connecting new business ventures to potential investment sources), and proactive entrepreneurship support and business acceleration services. The majority of the organizations also promote active networking and peer-to-peer connectivity opportunities and host events (including in-person and/or virtual events and informational webinars).

Table 24: Types of Programming Offered Across Assessed Programs

Program Area	Number Providing
Capital Access (Indirect)	11
Entrepreneurship Programming, Mentorship, & Acceleration	11
Networking & Events	9
R&D Advancement	5
Capital Access (Direct)	4
Information & Resource Aggregation	4
Innovation Space	4
Promotion, Inward Investment, & Trade	4
Producer Collaborations for Tech Piloting/Demo and New Crops	3
Education & Workforce	3
Public & Government Affairs	1

Source: TEconomy analysis.

Looking Forward

In considering AgriNovus Indiana programming, the one area that is not offered that TEconomy would recommend be prioritized for addition to the service portfolio is producer collaborations for technology piloting/demonstration and new crops. Wabash Heartland Innovation Network (WHIN) is an example of this, focused on building a collaborative network of participant farmers who provide services to entrepreneurial agriscience and agritech business for testing, piloting, and demonstrating company products. These types of efforts need to be expanded statewide.

That being said, the agbioscience development momentum that is building in Indiana points to a future in which all four agbioscience platforms are well positioned to grow as a result of its strengths in R&D, innovation, and other assets, and their line-of-sight to significant market growth opportunities. This is evidenced, in part, by the number of recent agbioscience-related economic development announcements, which include:

- Solinftec moving its global headquarters to Indiana and raising an additional \$60 million in venture capital.
- Inari expanding its footprint in Indiana as a result of an \$89 million venture capital investment announced in 2019.
- Italtollina's development of a \$6.8 million R&D center focused on the production of organic fertilizers, biostimulants, and beneficial microbials that are safe for the environment and human health.
- Mission Foods' plans to establish a manufacturing plant in Indiana, creating 544 new jobs when it opens.
- Premier BioSource's development of the company's first Indiana operation focusing on swine production for biomedical research and product development.
- Greenleaf Foods' plans to construct North America's largest plant-based protein manufacturing facility in Indiana, creating 460 jobs when it becomes operational.

- EnviroKure, a Pennsylvania-based producer of biologic amendments and organic fertilizers, decision to invest more than \$10 million to build a full-scale manufacturing plant in Indiana.
- Cormo USA Inc., a joint venture between Switzerland-based Cormo AG and Florida-based Sustainable Projects Group Inc., investment of approximately \$29.5 million to establish in Indiana its first U.S. production plant, creating 250 jobs. Cormo USA utilizes technology to turn corn field waste into sustainable products.

In Indiana, the agbiosciences will continue to represent an extremely important component of the state's economy, rooted in established and emerging strengths, and associated with large-scale market opportunities.

Chapter VII. Conclusions

The agbioscience industry sector continues to be an important economic engine for Indiana, presenting robust opportunities for future economic development. TEconomy's updated analysis for AgriNovus Indiana finds that the agbioscience industry continues to be a highly important and expanding advanced industry for Indiana. Inclusive of agricultural production, the agbioscience cluster directly employed 142,358 personnel in the state in 2018. The non-Primary Production component of the agbioscience cluster (activities outside of on-farm direct agricultural production) experienced 2.7 percent growth in employment between 2015 and 2018 (reaching a total of 93,174 jobs in 2018). Agbioscience is also notable in providing average wages that are significantly higher than the average private-sector wage in Indiana. Agbioscience sector wages averaged \$51,825 in 2018, 8.3 percent higher than the average Indiana private-sector wage of \$47,864.

Indiana's agbioscience industrial growth is driven by four key innovation platforms illustrated in Figure 22. Each of the four platforms is a focus point for significant innovation activity in Indiana, and this can be seen in the summary publication and patent statistics for each platform in Figure 22. They each are also home to a significant base of industry establishments, ranging from a high of 98 establishments in the Value-Added Food and Nutrition platform, to a low of 21 in the Animal Health and Nutrition platform. Combined, there are 24,502 personnel employed in the innovative companies driving these platforms, with the largest concentration being in the Value-Added Food and Nutrition platform (17,295 personnel, 70.6 percent of all platform employment).

Figure 22: Indiana Agbioscience Innovation Platforms

Indiana Agbioscience Innovation Platforms			
Value-Added Food and Nutrition	Plant Science and Crop Protection	Agricultural Equipment, Technologies, and Systems	Animal Health and Nutrition
Establishments = 98 Employment = 17,295 Publications = 641 Patents = 57	Establishments = 32 Employment = 2,764 Publications = 1,637 Patents = 736	Establishments = 47 Employment = 2,769 Publications = 110 Patents = 118	Establishments = 21 Employment = 1,674 Publications = 887 Patents = 106

Source: TEconomy Partners, LLC.

AgriNovus Indiana focuses its efforts on working with partners across the state to create the conditions necessary to fuel the growth of Indiana's agbioscience sector, ensuring its long-term economic sustainability and global competitiveness. The use of input/output analysis serves to demonstrate the current importance of Indiana agbioscience platforms to the Indiana economy both directly and through the multiplier effect that industry has on other Indiana industry sectors. For 2018, the analysis shows the agbioscience industry supported over 287,000 jobs in Indiana with a combined labor income of \$14.6 billion, and a total economic output generated of almost \$76 billion. Particularly notable is the generally strong performance of individual platforms across the Indiana agbioscience economy. It is found that all of the platforms (except Plant Science and Crop Protection) increased their employment and output economic impacts between 2012 and 2018. Value-Added Food and Nutrition increased its employment impact by 14.2 percent and its output impact by 13 percent. Agricultural Equipment, Technologies, and Systems increased its employment impact by 5.5 percent and its output impact by

15.6 percent; and Animal Health and Nutrition increased its employment impact by 18.6 percent and its output impact by 6 percent.

In Conclusion

AgriNovus Indiana has grown to become a signature economic development initiative for Indiana, providing a particularly wide range of programs and services in comparison with peer organizations domestically and internationally. Indiana is experiencing agbioscience-based economic growth; and, in three out of four AgriNovus Indiana target agbioscience platforms, there has been robust growth in employment and output impacts generated for Indiana. One platform, that of Plant Science and Crop Protection, has been more problematic in terms of its comparative performance; but, TEconomy notes that this is a cluster that nationally has experienced business consolidations and employment rationalizations through significant M&A activity. Into the future, all four agbioscience platforms in Indiana appear well positioned to grow, evidenced by strengths in R&D, innovation, and other assets, and their line-of-sight to significant market growth opportunities.

Appendix A. Regional Agbioscience Analysis

Central Indiana's Agbioscience Innovation Drivers

The analysis that follows delves deeply into Central Indiana's position within the agbiosciences in terms of the industrial and innovation base that is driving this industrial sector.²⁶ While primarily urban, Central Indiana does indeed have a strong agbioscience sector. It is home to leading global innovators including Corteva Agriscience, Elanco, and AgReliant Genetics, as well as a rising number of start-ups, such as Epogee. At its outer boundaries, there is also rich agricultural production. The region is also focused on developing and retaining the necessary talent for a 21st Century workforce; supporting start-up businesses; and advancing other key sectors that are closely aligned with the agbiosciences, including tech/Internet of Things (IoT) and life sciences. Under the leadership of the Central Indiana Corporate Partnership, the Indy Chamber, and others, initiatives like the Indiana Biosciences Research Institute and 16 Tech make the region an ideal home for agbioscience expansion.

Overall Agbioscience Industry

The total agbioscience industry (including farm production) in Central Indiana employed 30,286 personnel across the full value chain in 2018 (Table A-1), increasing 1.3 percent between 2015 and 2018. While not highly concentrated in the region (location quotient or LQ of 0.7), the agbioscience average wage was substantially higher than the average wage for the total private sector (\$66,805 versus \$52,588).

As Figure A-1 illustrates, three agbioscience subsectors drove economic growth in Central Indiana.

- The largest sector in Central Indiana, Food, Nutrition, and Health, has employment of 12,405, increasing 11.3 percent between 2015 and 2018.
- Ag and Biological Research, Testing, and Services employed 3,559 throughout the region, increasing 9.9 percent during the time period. With an LQ of 1.22, this subsector has a 22 percent greater employment concentration in the region relative to the national average.
- Wholesaling, Distribution, and Storage Operations employed 2,795 throughout the region, increasing 5.8 percent during the time period.

During this time, the Inputs to Production subsector saw a significant employment decline (27.1 percent); however, TEconomy cautions that the apparent decline may be a result of NAICS code reclassification of Corteva Agriscience and not the loss of actual jobs within the region.

²⁶ Central Indiana includes the following counties: Boone, Hamilton, Hancock, Hendricks, Johnson, Marion, Morgan, and Shelby.

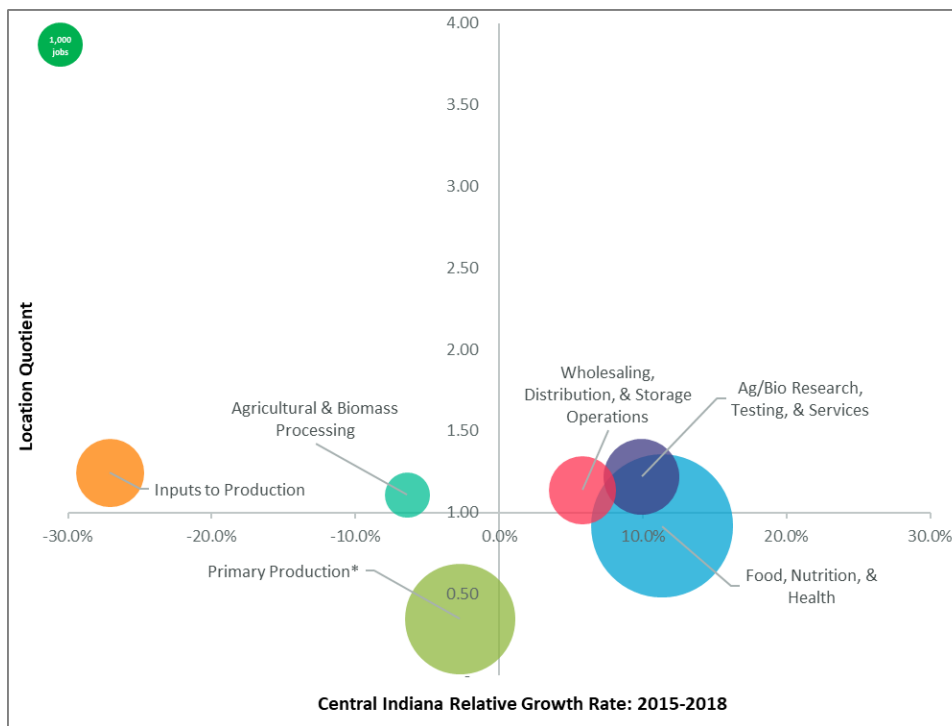
Table A-1. Central Indiana Agbioscience Establishments, Employment, Specialization, and Wages

AgBio Sector	Establish- ments 2018*	Estab. Growth, 2015– 2018*	Employ- ment 2018	2018 Emp. LQ	Emp. Growth, 2015– 2018	Average Wages 2018*
Ag/Bio Research, Testing & Services	228	2.7%	3,559	1.22	9.9%	\$66,313
Inputs to Production	114	2.0%	2,857	1.24	-27.1%	\$84,086
Primary Production w/Farm Proprietors Employment*	254	8.7%	7,417	0.35	-2.7%	\$43,499
Agricultural & Biomass Processing	15	-16.7%	1,253	1.11	-6.4%	\$77,196
Food, Nutrition & Health	189	31.9%	12,405	0.92	11.3%	\$68,399
Wholesaling, Distribution & Storage Operations	67	-2.9%	2,795	1.14	5.8%	\$50,756
Total AgBio w/Farm Proprietors Employment*	867	8.7%	30,286	0.70	1.3%	\$66,085
Total Private Sector	47,890	4.0%	883,419	1.00	5.2%	\$52,588

Source: TEconomy analysis of enhanced census of employment and wages (CEW) data from IMPLAN and U.S. Bureau of Economic Analysis (BEA) Farm Proprietors employment.

Note: * Non-employment metrics for establishments and wages in Primary Production and Total AgBio Supersector rows are for CEW-based corporate employment only.

Figure A-1. Central Indiana Comparative Agbioscience Sector Performance (2015–2018)



Source: TEconomy analysis of enhanced CEW data from IMPLAN and U.S. BEA Farm Proprietors employment.

Central Indiana’s Agbioscience Innovation Base

Central Indiana has a strong industrial and employment base in the agbioscience sector. The competitiveness of the entire agbioscience value chain is driven in large part by innovation. There are in Central Indiana a subset of companies that leverage 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. Therefore, to truly understand the economic drivers of the agbioscience sector in Central Indiana, the previous industrial overview of the region’s agriculture and agbioscience base needs to be supplemented by a micro analysis of specific areas where agbioscience innovation activity is occurring. This section profiles the innovation base of agbioscience activity in Central Indiana, including identifying the key firms and universities involved and detailing their activities in publishing research, patenting, and securing financial resources and investment capital.

Currently, the Central Indiana region is home to 38 innovative agbioscience establishments accounting for 4,873 employees (Table A-2). In the region’s agbioscience industry, three innovation sectors account for most of the employment, with animal health and nutrition products accounting for 910 (19 percent), plant science and crop protection reaching more than 2,000 (42 percent), and value-added human food and nutrition products accounting for 1,867 jobs (38 percent). Key regional firms include major employers such as Corteva Agriscience, Elanco Animal Health, and Weston Foods US; innovation-driven mid-sized firms such as Beck’s Hybrids, Micronutrients, and SePRO Corporation; and new emerging companies such as BrewLogix (fka SteadyServ) and Epogee.

Table A-2. Central Indiana’s Agbioscience Innovation Company Employment (2019)

Indiana Agbioscience Innovation Sector	Establishments	Employment
Agricultural Equipment, Technologies, and Systems	4	70
Animal Health and Nutrition	4	910
Plant Science and Crop Protection	6	2,026
Value-Added Food and Nutrition	24	1,867
Central Indiana Total	38	4,873

Source: TEconomy analysis and estimates using Dun & Bradstreet database.

The Central Indiana region’s innovation performance is strongly driven by the private sector efforts of Corteva and Elanco (Table A-3). These two firms account for the vast majority of both research publications and patents during the 2015–2019 period (Tables A-4 through A-6). While there was no federally supported research and innovation through Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) awards during the time period, the region saw substantial venture capital investments, nearly \$90 million during this period (Table A-7).

Table A-3. Central Indiana Agbioscience Key Innovation Metrics Summary (2015–2019)

Agbioscience Research Publications
559 publications. Key innovation areas include plant science and crop protection and animal health and nutrition products.
Key research institutions:
<ul style="list-style-type: none">• Corteva (including precursor orgs)—243 publications

- Elanco—96 publications
- Eli Lilly & Co.—18 publications
- Micronutrients USA—16 publications

Agbioscience Patents

928 patents across 18 Central Indiana–located institutions.

Key innovation institutions:

- Corteva (including predecessors and subsidiaries)—844 patents
- CNH Industrial America LLC—19 patents
- Indiana University Research and Technology Corporation—15 patents

Agbioscience Innovation Resources and Capital

SBIR/STTR Awards	None
Venture Capital	34 Deals; \$60,020,000 in VC Funding

Source: TEconomy analysis.

Table A-4. Central Indiana Agbioscience Publications, by Innovation Sector (2015–2019)

Indiana Agbioscience Innovation Sector	Total Publications by Innovation Sector
Agricultural Equipment, Technologies, and Systems	4
Animal Health and Nutrition Products	192
Plant Science and Crop Protection	224
Value-Added Human Food and Nutrition Products	96
Multidisciplinary/Crosscutting	43
Central Indiana Total	559

Source: TEconomy analysis of Clarivate Analytics' Web of Science publications database.

Table A5. Central Indiana Agbioscience Publications, by Innovation Sector, 2015-2019

Key Author Institutions	Agricultural equipment technologies and systems	Animal health and nutrition	Plant science and crop protection	Value-added human food and nutrition	Multi-disciplinary/ Cross-cutting	Total
Corteva (incl. predecessor organizations)	3	6	143	34	18	204
Elanco		70		23	3	96
IUPUI		4	39	6	14	63
Indiana University School of Medicine		32	6	6	2	46
Eli Lilly & Co.		2		16		18
United Animal Health		16				16
Micronutrients		16				16
MiraVista Diagnostics		10				10
Butler University			7	2		9
Avian & Exotic Animal Clinic		8				8

University of Indianapolis			5			5
All Other Central Indiana Institutions	1	36	27	9	3	76
Central Indiana Total	4	197	224	96	43	564

Source: TEconomy analysis of Clarivate Analytics' Web of Science publications database.

Table A-6. Central Indiana Agbioscience Patents, by Assignee (2015–2019)

Central Indiana Patent Assignee	Number of Patents
Corteva (including predecessors & subsidiaries)	844
CNH Industrial America LLC	19
Indiana University Research & Technology Corporation	15
Elanco US Inc.	9
Limagrain (AgReliant)	7
Hydro-Gear	6
SePRO Corporation	5
Cook General Biotechnology LLC	4
United Animal Health	3
Eco Sports Group Inc.	3
Activation Technologies LLC	2
Aircom Manufacturing	2
Beck's Hybrids	2
GreensGroomer WorldWide Inc.	2
Nico Corporation	2
Relevo Inc.	1
Smart Animal Training Systems LLC	1
Specialty Coating Systems Inc.	1

Source: TEconomy analysis of Clarivate Analytics' Derwent Innovation patent analysis database.

Table A-7. Central Indiana Agbioscience-Related Venture Capital Investments (2015–2019)

Central Indiana Agbioscience Firm	Number of 2015–2019 Deals	Total 2015–2019 VC Investments
Agricultural Equipment, Technologies, and Systems	8	\$1,320,000
Agrisolve	1	\$830,000
Algaeon	1	\$260,000
Aggressively Organic	2	\$230,000
Plant Science and Crop Protection	1	\$3,260,000
Blue Crop Group	1	\$3,260,000
Value-Added Food and Nutrition	29	\$55,440,000
BrewLogix (fka Steady Serv)	4	\$15,760,000
Uncle Nearest	3	\$14,400,000
Epogee	2	\$10,600,000

Central Indiana Agbioscience Firm	Number of 2015–2019 Deals	Total 2015–2019 VC Investments
Beach Whiskey	2	\$7,780,000
Hotel Tango Whiskey	3	\$2,400,000
SoChatti	3	\$1,350,000
Newfangled Confections	2	\$700,000
West Fork Whiskey Company	3	\$460,000
Lonkero	1	\$390,000
Scotty's Brewhouse	1	\$390,000
Market Wagon	1	\$360,000
New Day Craft	1	\$350,000
Ash & Elm Cider Company	1	\$300,000
Blue Marble Cocktails	1	\$200,000
DSTest Laboratories	1	Accelerator
Central Indiana Agbioscience Total	34	\$60,020,000

Source: TEconomy analysis of Pitchbook venture financing database.

Northeast Indiana's Agbioscience Innovation Drivers

The analysis that follows delves deeply into Northeast Indiana's position within the agbiosciences in terms of its industrial and innovation base that are driving this important industrial sector.²⁷

Northeastern Indiana is home to some of the state's most productive crop and livestock enterprises. Its strong commodity base and robust food-processing and agricultural-related manufacturing sectors position the region for long-term opportunities to advance the technologically driven agbiosciences. The region is also focused on developing and retaining the necessary talent for a 21st Century workforce with relevant educational programs at Huntington University, Trine University, Manchester University, Grace College, and Ivy Tech. Under the leadership of the Northeast Indiana Regional Partnership, the comprehensive food and agriculture cluster strategy that is currently being advanced will focus additional efforts on agbioscience promotion and expansion.

Overall Agbioscience Industry

The total agbioscience industry (including farm production) in Northeast Indiana employed 21,878 personnel across the full value chain in 2018 (Table A-8), declining 4.6 percent between 2015 and 2018. The agbioscience industry in Northeast Indiana stands out as a regional "specialization" in its employment concentration, which is 33 percent greater than the national average, as measured by an LQ. In addition, the agbioscience average wage was on par with the total private sector (\$44,055 versus \$45,114).

As Figure A-2 illustrates, two of the major agbioscience subsectors are also considered regional specializations (LQ > 1.2):

- The largest sector in Northeast Indiana, Primary Production (farming), which employs 12,762, has an LQ of 1.58, indicating that employment in this sector is 58 percent greater than would be expected given national averages.
- Inputs to Production is twice as concentrated in the region relative to the national average (LQ = 2.06), although employment declined 17.9 percent during the time period.

While not yet specialized, two agbioscience subsectors experienced significant growth between 2015 and 2018:

- Ag/Bio Research, Testing, and Services grew 18.1 percent, and
- Wholesaling, Distribution, and Storage Operations grew 17.1 percent.

²⁷ Northeast Indiana includes the following counties: Adams, Allen, DeKalb, Huntington, Kosciusko, LaGrange, Noble, Steuben, Wabash, Wells, and Whitley.

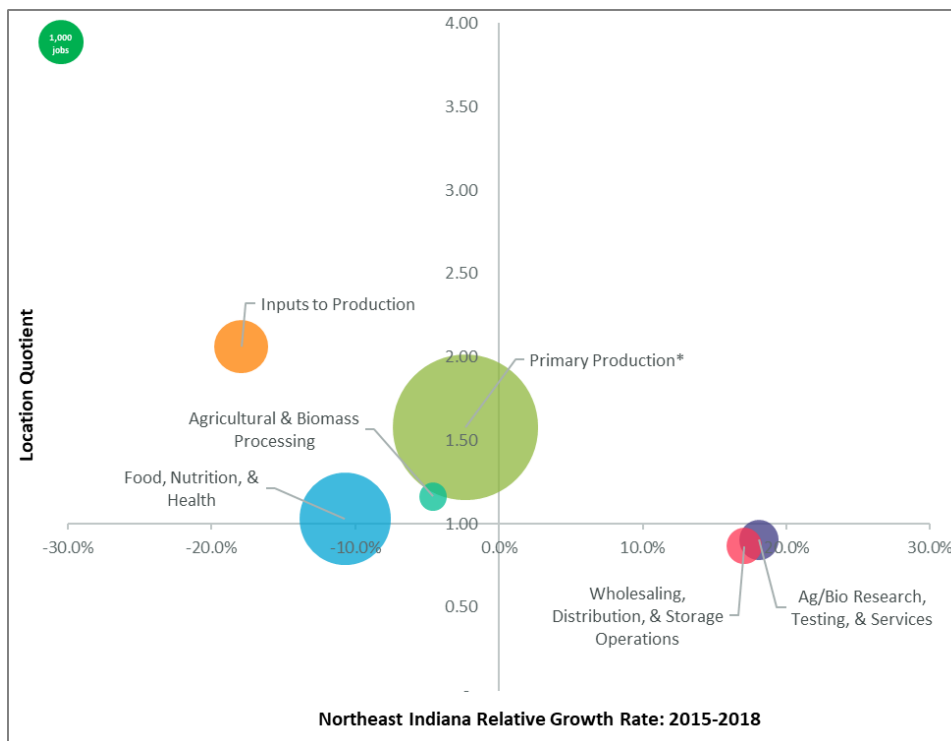
Table A-8. Northeast Indiana Agbioscience Establishments, Employment, Specialization, and Wages

AgBio Sector	Establish- ments 2018*	Estab. Growth, 2015– 2018*	Employ- ment 2018	2018 Emp. LQ	Emp. Growth, 2015– 2018	Average Wages 2018*
Ag/Bio Research, Testing & Services	83	-0.3%	972	0.90	18.1%	\$37,306
Inputs to Production	125	1.0%	1,746	2.06	-17.9%	\$60,020
Primary Production w/Farm Proprietors Employment*	315	7.0%	12,762	1.58	-2.3%	\$36,159
Agricultural & Biomass Processing	15	7.1%	484	1.16	-4.6%	\$64,825
Food, Nutrition & Health	112	16.4%	5,127	1.03	-10.7%	\$42,103
Wholesaling, Distribution & Storage Operations	42	-2.3%	786	0.87	17.1%	\$41,602
Total AgBio w/Farm Proprietors Employment*	691	5.7%	21,878	1.33	-4.6%	\$44,055
Total Private Sector	17,516	2.3%	325,314	1.00	3.3%	\$45,114

Source: TEconomy analysis of enhanced CEW data from IMPLAN and U.S. BEA Farm Proprietors employment.

Note: * Non-employment metrics for establishments and wages in Primary Production and Total AgBio Supersector rows are for CEW-based corporate employment only.

Figure A-2. Northeast Indiana Comparative Agbioscience Sector Performance (2015–2018)



Source: TEconomy analysis of enhanced CEW data from IMPLAN and U.S. BEA Farm Proprietors employment.

Northeast Indiana’s Agbioscience Innovation Base

Northeast Indiana has a strong industrial and employment base in the agbioscience sector. The competitiveness of the entire agbioscience value chain is driven in large part by innovation. There are in Northeast Indiana a subset of companies that leverage 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. Therefore, to truly understand the economic drivers of the agbioscience sector in Northeast Indiana, the previous industrial overview of the region’s agriculture and agbioscience base needs to be supplemented by a micro analysis of specific areas where agbioscience innovation activity is occurring. This section profiles the innovation base of agbioscience activity in Northeast Indiana, including identifying the key firms and universities involved and detailing their activities in publishing research, patenting, and securing financial resources and investment capital.

Currently, the Northeast Indiana region is home to 36 innovative agbioscience firms accounting for 4,342 employees (Table A-9). In the region’s agbioscience industry, two innovation sectors account for most of the employment, with value-added human food and nutrition products accounting for 2,545 jobs (59 percent) and agricultural equipment, technologies, and systems accounting for 1,463 jobs (34 percent). Key regional firms include ag system manufacturer CTB; Whiteshire Hamroc, a unique agricultural operation blending integrated farming with a world-class swine-breeding program (including the related firm Airworks and PureTek Genetics); other major farming operations including Maple Leaf Farms and Miller Poultry; and food-processing companies such as Inventure Foods and Perfection Bakeries. The Northeast Indiana region is also home to several emerging, technology-based companies including Biodyne, Owl Manor Medical, Artemis International, and Trellis Growing Systems.

Table A-9. Northeast Indiana’s Agbioscience Innovation Company Employment (2019)

Indiana Agbioscience Innovation Sector	Establishments	Employment
Agricultural Equipment, Technologies, and Systems	9	1,463
Animal Health and Nutrition	7	200
Plant Science and Crop Protection	7	134
Value-Added Food and Nutrition	13	2,545
Northeast Indiana Total	36	4,342

Source: TEconomy analysis and estimates using Dun & Bradstreet database.

The Northeast Indiana region’s innovation performance was driven during the 2015–2019 period by the private sector efforts of a number of firms, including CTB, Maple Leaf Farms, Syngenta, and Trellis Growing Systems (Table A-10). Data for publications, patents, and SBIR/STTR awards are shown on Tables A-11 through A-14. Trellis Growing Systems received federally supported research and innovation funding through two SBIR/STTR awards during the time period, and the region saw one venture capital investments of \$1.2 million to Owl Manor Medical (Table A-15).

Table A-10. Northeast Indiana Agbioscience Key Innovation Metrics Summary (2015–2019)

Agbioscience Research Publications
47 Publications. Key innovation areas include: plant science and crop protection and animal health and nutrition products. Key research institutions:

- Indiana University/Purdue University—Fort Wayne—21 publications
- Maple Leaf Farms—8 publications
- Manchester University—3
- Trellis Growing Systems—2

Agbioscience Patents

33 patents across 5 Northeast Indiana-located institutions.

Key innovation institutions:

- CTB Inc.—18 patents
- Syngenta Participations AG—10 patents

Agbioscience Innovation Resources and Capital

SBIR/STTR Awards	2 USDA Awards; \$568,779
Venture Capital	1 Deal; \$1,200,000 in VC Funding

Source: TEconomy analysis.

Table A-11. Northeast Indiana Agbioscience Publications, by Innovation Sector (2015–2019)

Indiana Agbioscience Innovation Sector	Total Publications by Innovation Sector
Agricultural Equipment, Technologies, and Systems	1
Animal Health and Nutrition	18
Plant Science and Crop Protection	22
Value-Added Human Food and Nutrition	2
Multidisciplinary/Crosscutting	4
Northeast Indiana Total	47

Source: TEconomy analysis of Clarivate Analytics' Web of Science publications database.

Table A12. Northeast Indiana Agbioscience Publications, by Innovation Sector, 2015-2019

Key Author Institutions	Agricultural equipment technologies and systems	Animal health and nutrition	Plant science and crop protection	Value-added human food and nutrition	Multi-disciplinary/ Cross-cutting	Total
Purdue University - Fort Wayne		6	16	1	3	26
Maple Leaf Farms		8				8
Northeast Indiana Vet		3				3
Manchester University			2			
Trellis Growing System			2			2
All Other Northeast Indiana Institutions	1	4	2	1	1	11
Northeast Indiana Total	1	18	22	2	4	47

Source: TEconomy analysis of Clarivate Analytics' Web of Science publications database.

Table A-13. Northeast Indiana Agbioscience Patents by Assignee (2015–2019)

Northeast Indiana Patent Assignee	Number of Patents
CTB Inc.	18
Syngenta Participations AG	10
E-Collar Technologies	3
Whiteshire/Hamroc LLC	1
Par-Kan Company	1

Source: TEconomy analysis of Clarivate Analytics' Derwent Innovation patent analysis database.

Table A-14. Northeast Indiana Agbioscience-Related SBIR/STTR Awards (2015–2019)

Company	Federal Agency	Phase	Award Year	Award Amount
Trellis Growing Systems	USDA (SBIR)	I	2016	\$99,961
	USDA (SBIR)	II	2018	\$468,818
<i>Project: Low Trellis Production, Harvesting System and Marketing Tools for Locally-Grown Hops</i>				

Source: TEconomy analysis of data from SBIR.gov awards website.

Table A-15. Northeast Indiana Agbioscience-Related Venture Capital Investments (2015–2019)

Northeast Indiana Agbioscience Firm	Number of 2015–2019 Deals	Total 2015–2019 VC Investments
Animal Health and Nutrition	1	\$1,200,000
Owl Manor Veterinary	1	\$1,200,000
Northeast Indiana Agbioscience Total	1	\$1,200,000

Source: TEconomy analysis of Pitchbook venture financing database.

Wabash Heartland's Agbioscience Innovation Drivers

The analysis that follows delves deeply into the Wabash Heartland's position within the agbiosciences in terms of its industrial and innovation base that are driving this important industrial sector.²⁸ The Wabash Heartland region is home to some of the state's most productive crop and livestock enterprises. The region is also home to Purdue University, whose research and educational training capabilities anchor it as a global leader in agbioscience innovation. Most excitingly, the region has seen a significant increase in recent years in innovation led by start-up endeavors that are attracting significant new investment to the region through firms such as Inari, Solinftec, Rogo Ag, DTN (fka Spensa Technologies), VinSense, Phicrobe, Progeny Drone, and ZeaVaxx LLC. This renewed focus/energy is in part a result of a regional strategic initiative called the Wabash Heartland Innovation Network (WHIN) that received a \$40 million grant from the Lilly Endowment in 2018 to help harness the power of Internet-enabled sensors to develop the region into a global epicenter of digital agricultural and next-generation manufacturing. The region's strong commodity base and enterprising agribusinesses help position the region for long-term opportunities to advance the technologically driven agbiosciences.

Overall Agbioscience Industry

The total agbioscience industry (including farm production) in the Wabash Heartland region employed 16,382 personnel across the full value chain in 2018 (Table A-16), declining 2.1 percent between 2015 and 2018. The agbioscience industry in the Wabash Heartland region stands out as a regional "specialization" in its employment concentration, which is 2.5 times greater than the national average, as measured by an LQ. In addition, the agbioscience average wage was higher than the average wage for the total private sector (\$48,099 versus \$43,999).

As Figure A-3 illustrates, five of the six agbioscience subsectors are also considered regional specializations (LQ > 1.2):

- The largest subsector in the region, Food, Nutrition, and Health, which employs 6,816, has an LQ of 3.57, indicating that employment in this sector is 3.5 times greater than would be expected given national averages.
- The second-largest subsector in the region, Primary Production (farming), which employs 6,638, has an LQ of 2.13, indicating that employment in this sector is 2 times greater than would be expected given national averages.
- Inputs to Production is 4.4 times as concentrated in the region relative to the national average (LQ = 4.39), although employment declined 12 percent during the time period.
- Although much smaller in employment size, both Agricultural and Biomass Processing (LQ = 3.88) and Wholesaling, Distribution, and Storage Operations (LQ = 1.28) are both specialized in the region.

²⁸ The Wabash Heartland region includes the following counties: Benton, Carroll, Cass, Clinton, Fountain, Montgomery, Pulaski, Tippecanoe, Warren, and White.

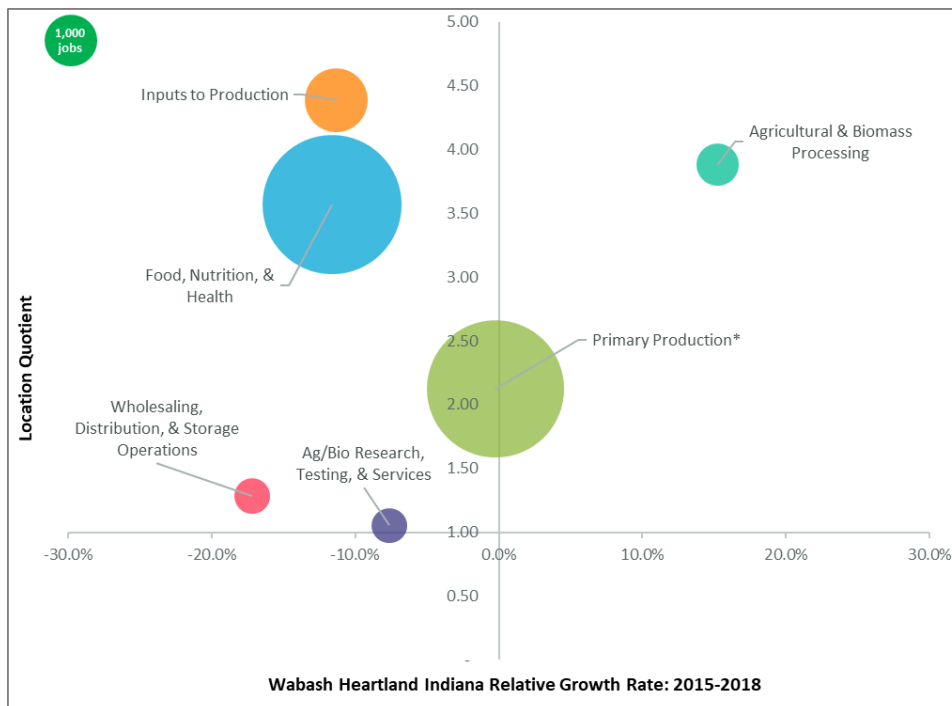
Table A-16: Wabash Heartland Indiana Agbioscience Establishments, Employment, Specialization, and Wages

AgBio Sector	Establishments 2018*	Estab. Growth, 2015–2018*	Employment 2018	2018 Emp. LQ	Emp. Growth, 2015–2018	Average Wages 2018*
Ag/Bio Research, Testing & Services	44	-5.1%	435	1.05	5.3%	\$35,700
Inputs to Production	110	3.8%	1,426	4.39	-12.0%	\$52,847
Primary Production w/Farm Proprietors Employment*	267	8.2%	6,638	2.13	-1.0%	\$39,526
Agricultural & Biomass Processing	6	0.0%	620	3.88	15.6%	\$90,511
Food, Nutrition & Health	56	11.9%	6,816	3.57	-2.1%	\$46,464
Wholesaling, Distribution & Storage Operations	38	2.7%	447	1.28	-10.0%	\$50,222
Total AgBio w/Farm Proprietors Employment*	521	5.9%	16,382	2.58	-2.1%	\$48,099
Total Private Sector	7,261	1.5%	124,904	1.00	3.6%	\$43,999

Source: TEconomy analysis of enhanced CEW data from IMPLAN and U.S. BEA Farm Proprietors employment.

Note: * Non-employment metrics for establishments and wages in Primary Production and Total AgBio Supersector rows are for CEW-based corporate employment only.

Figure A-3. Wabash Heartland Comparative Agbioscience Sector Performance (2015–2018)



Source: TEconomy analysis of enhanced CEW data from IMPLAN and U.S. BEA Farm Proprietors employment.

Wabash Heartland’s Agbioscience Innovation Base

The Wabash Heartland region has a strong industrial and academic base in the agbioscience sector. The competitiveness of the entire agbioscience value chain is driven in large part by innovation. There are in the Wabash Heartland region a subset of companies that leverage 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. Therefore, to truly understand the economic drivers of the agbioscience sector in the Wabash Heartland region, the previous industrial overview of the region’s agriculture and agbioscience base needs to be supplemented by a micro analysis of specific areas where agbioscience innovation activity is occurring. This section profiles the innovation base of agbioscience activity in the Wabash Heartland region, including identifying the key firms and universities involved and detailing their activities in publishing research, patenting, and securing financial resources and investment capital.

The Wabash Heartland region, as home to Purdue University’s major agbioscience research and extension operations, is a key driver of Indiana’s statewide agbioscience efforts. Beyond Purdue, the Wabash Heartland region is home to 34 innovative agbioscience firms accounting for 4,610 employees (Table A-17). The region is dominated by employment within the value-added human food and nutrition products sector accounting for 90 percent of the agbioscience industry total. Major food-processing operations, covering a broad spectrum of food types, are located in the Wabash Heartland region, including the Indiana Packers Corporation (IPC), Tyson Foods, and Frito-Lay, and ingredient suppliers such as Tate & Lyle and Archer-Daniels-Midland Company (ADM). Important seed development entities also have locations in the Wabash Heartland region, including Ag Alumni Seed, Bayer (fka Monsanto), Specialty Hybrids, and Inari. The region is also host to a variety of emerging technology-driven agbioscience firms, including JUA Technologies International, Solinftec, Rogo Ag, DTN (fka Spensa Technologies), VinSense, GRYFN, and Progeny Drone.

Table A-17. Wabash Heartland’s Agbioscience Innovation Company Employment (2019)

Indiana Agbioscience Innovation Sector	Establishments	Employment
Agricultural Equipment, Technologies, and Systems	11	262
Animal Health and Nutrition	2	6
Plant Science and Crop Protection	6	198
Value-Added Food and Nutrition	15	4,144
Wabash Heartland Total	34	4,610

Source: TEconomy analysis and estimates using Dun & Bradstreet database.

The size and magnitude of the Purdue University’s agbioscience research and innovation enterprise is readily apparent as Purdue accounts for more than 2,500 publications (97 percent) of the region’s research publications (Table A-18). The Agricultural Research Service (ARS) of the United States Department of Agriculture (USDA) accounts for 219 publications, with many of those being joint publications with Purdue faculty and researchers. Not surprisingly, Purdue also leads the region’s agbioscience patenting activity. Data for publications, patents, and SBIR/STTR awards are shown on Tables A-19 through A-22. Beyond Purdue’s involvement in agbioscience innovation funding, the Wabash Heartland region has also received the largest amount of agbioscience-related SBIR funding—to 4 companies who received 7 awards totaling nearly \$2.7 million over the period. The region also saw

substantial venture capital investments, nearly \$5 million invested in 15 deals during this period (Table A-23). It is important to note that this total does not include Inari's 2019 investment of \$89 million since the company is headquartered in Cambridge, Massachusetts, which is the location of record for the investment, nor the \$60 million investment in Solinftec received in early 2020.

Table A-18. Wabash Heartland Agbioscience Key Innovation Metrics Summary (2015–2019)

Agbioscience Research Publications	
2,610 Publications. Due to presence of Purdue University, strengths across all innovation sectors, especially plant science and nutrition products.	
Key research institutions:	
<ul style="list-style-type: none"> Purdue University—2,522 publications USDA ARS—219 publications 	
Agbioscience Patents	
37 patents across 6 Wabash Heartland–located institutions.	
Key innovation institutions:	
<ul style="list-style-type: none"> Purdue Research Foundation—28 patents Tribine Industries LLC—4 patents 	
Agbioscience Innovation Resources and Capital	
SBIR Awards	7 Awards; \$2,661,438 in Funding
Other Federal Tech Development Awards	1 Award; \$2,250,000 in Funding
Venture Capital	16 Deals; \$4,690,000 in VC Funding

Source: TEconomy analysis.

Table A-19. Wabash Heartland Agbioscience Publications, by Innovation Sector (2015–2019)

Indiana Agbioscience Innovation Sector	Total Publications by Innovation Sector
Agricultural Equipment, Technologies, and Systems	100
Animal Health and Nutrition	647
Plant Science and Crop Protection	1,121
Value-Added Human Food and Nutrition	502
Multidisciplinary/Crosscutting	240
Wabash Heartland Total	2,610

Source: TEconomy analysis of Clarivate Analytics' Web of Science publications database.

Table A20. Wabash Heartland Agbioscience Publications, by Innovation Sector, 2015-2019

Key Author Institutions	Agricultural equipment technologies and systems	Animal health and nutrition	Plant science and crop protection	Value-added human food and nutrition	Multi-disciplinary/ Cross-cutting	Total
Purdue University	96	630	1,077	497	222	2,522
USDA ARS - West Lafayette	15	49	114	16	25	219
<i>Livestock Behavior Research</i>		45		8	2	55
<i>National Soil Erosion Research</i>	10		22	2	26	60
<i>Crop Production & Pest Control Research</i>		1	26		1	28
All Other Wabash Heartland Indiana Institutions		3	8	2	1	14
Total	100	647	1,121	502	240	2,610

Source: TEconomy analysis of Clarivate Analytics' Web of Science publications database.

Table A-21. Wabash Heartland Agbioscience Patents, by Assignee (2015–2019)

Wabash Heartland Patent Assignee	Number of Patents
Purdue Research Foundation	28
Tribine Industries LLC	4
Tate & Lyle Ingredients Americas	2
Ash Access Technology Inc.	1
Muffin Incorporated	1
Perfinity Biosciences Inc.	1

Source: TEconomy analysis of Clarivate Analytics' Derwent Innovation patent analysis database.

Table A-22. Wabash Heartland Agbioscience-Related SBIR/STTR and Other Federal Awards (2015–2019)

Company	Federal Agency	Phase	Award Year	Award Amount
JUA Technologies International LLC	USDA (SBIR)	I	2019	\$100,000
<i>Project: Smart Multipurpose Solar Dehydration Device for Value Addition to Specialty Crops</i>				
NutraMaize LLC	USDA (SBIR)	I	2017	\$99,997
<i>Project: High Carotenoid Orange Corn for Poultry Health</i>				
	NSF (STTR)	I	2017	\$225,000
<i>Project: Utilizing Natural Variation to Increase the Antioxidant Carotenoid Content in High Yielding Corn Varieties</i>				
	NSF (STTR)	II	2019	\$747,432
<i>Project: Developing High Carotenoid Orange Corn for Large-scale Commercial Adoption</i>				
Phytoption LLC	NSF (SBIR)	II	2016	\$749,785
<i>Project: New ingredients technology to enhance the safety, quality, and value of active substances for pharmaceuticals, food, and personal care</i>				

VinSense LLC	NSF (SBIR)	II	2017	\$514,295
<i>Project: Visual Information eNvironment for Effective Agricultural Management and Sustainability</i>				
	NSF (STTR)	I	2016	\$224,949
<i>Project: Visual Information eNvironment for Effective Agricultural Management and Sustainability</i>				
GRYFN	DOE (ARPA-E)		2019	\$2,250,000
<i>Project: SubAward to Purdue University TERRA Award</i>				

Source: TEconomy analysis of data from SBIR.gov awards website.

Table A-23. Wabash Heartland Agbioscience-Related Venture Capital Investments (2015–2019)

Wabash Heartland Agbioscience Firm	Number of 2015–2019 Deals	Total 2015–2019 VC Investments
Agricultural Equipment, Technologies, and Systems	11	\$4,540,000
DTN (fka Spensa Technologies)	2	\$4,050,000
Rogo	1	\$200,000
VinSense	4	\$150,000
Phicrobe	1	\$80,000
Progeny Drone	1	\$60,000
J&H Consulting	1	Accelerator
Agsoil Analytics	1	Accelerator
Animal Health and Nutrition	3	\$140,000
Greater Innovations	1	\$100,000
ZeaVaxx	1	\$20,000
Teichos Laboratories	1	\$20,000
Value-Added Food and Nutrition	1	\$10,000
NouvEau	1	\$10,000
JUA Technologies International	1	Accelerator
Wabash Heartland Agbioscience Total	16	\$4,690,000

Source: TEconomy analysis of Pitchbook venture financing database.

Appendix B. NAICS Codes Defining Agbiosciences

Segment	SubSegment	NAICS Code	NAICS Description
Ag/Bio Research, Testing, & Services	Biological and Agricultural R&D	54171AG	Biological & Agricultural R&D
	Testing Laboratories	541380AG	Testing Laboratories
	Veterinary Services	541940	Veterinary Services
Inputs to Production	Ag Machinery & Equipment	333111	Farm Machinery & Equipment Manufacturing
		423820	Farm/Garden Machinery & Equipment Merchant Wholesalers
	Agricultural Chemicals	325311	Nitrogenous Fertilizer Manufacturing
		325312	Phosphatic Fertilizer Manufacturing
		325314	Fertilizer (Mixing Only) Manufacturing
		325320	Pesticide & Other Agricultural Chemical Manufacturing
	Agricultural Inputs Wholesaling	424910	Farm Supplies Merchant Wholesalers
Veterinary Medicines & Vaccines	325412AG	Pharmaceutical Preparation Manufacturing	
Primary Production	Agricultural & Biomass Production	111	Crop Production
		113	Forestry & 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
		311224	Soybean & Other Oilseed Processing
		311225	Fats/Oils Refining & Blending
		311313	Beet Sugar Manufacturing
		311314	Cane 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
	Botanicals, Diagnostics, and Biological Products	312140	Distilleries
		325411	Medicinal & Botanical Manufacturing
		325413	In-Vitro Diagnostic Substance Manufacturing
	325414	Biological Product (except Diagnostic) Manufacturing	
	Food Processing & Manufacturing	3111	Animal Food Manufacturing
		311230	Breakfast Cereal Manufacturing
		3113	Sugar & Confectionery Product Manufacturing
		3114	Fruit/Vegetable Preserving & Specialty Food Manufacturing
		3115	Dairy Product Manufacturing
		3116	Animal Slaughtering & Processing
3117		Seafood Product Preparation & Packaging	
3118		Bakeries & Tortilla Manufacturing	
3119		Other Food Manufacturing	
Wholesaling, Distribution, & Storage Operations	Agricultural Commodity Wholesaling	424510	Grain & Field Bean Merchant Wholesalers
		424520	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 & Meat Product Merchant Wholesalers
		424480	Fruit & 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 or specific company employment data to estimate the agbioscience-based NAICS employment.		

Appendix C. Indiana Agbioscience VC Investments, 2015-2019

Innovation Area and Company	# of Deals	Total Investment (\$M)
Agricultural Equipment, Technologies, and Systems	21	6.47
DTN (fka Spensa Technologies)	2	4.05
Agrisolve	1	0.83
The Bee Corp	3	0.51
Algaeon	1	0.26
Aggressively Organic	2	0.23
Rogo	1	0.20
VinSense	4	0.15
Heliponix	3	0.10
Phicrobe	1	0.08
Progeny Drone	1	0.06
Agsoil Analytics	1	Accelerator
J&H Consulting	1	Accelerator
Animal Health and Nutrition	4	1.34
Owl Manor Veterinary	1	1.20
Greater Innovations	1	0.10
ZeaVaxx	1	0.02
Teichos Laboratories	1	0.02
Plant Science and Crop Protection	1	3.26
Blue Crop Group	1	3.26
Value-Added Food and Nutrition	40	57.94
BrewLogix (fka Steady Serv)	4	15.76
Uncle Nearest	3	14.4
Epogee	2	10.6
Beach Whiskey	2	7.78
Hotel Tango Whiskey	3	2.40
SoChatti	3	1.35
Cardinal Spirits	1	0.75
Newfangled Confections	2	0.70
Green Sense Farms	1	0.61
Crazy Horse Hops	2	0.48
West Fork Whiskey Company	3	0.46
Scotty's Brewhouse	1	0.39
Lonkero	1	0.39
Market Wagon	1	0.36
New Day Craft	1	0.35
Ash & Elm Cider Company	1	0.30
Switchyard Holdings	2	0.27
Hard Truth Distilling Company	1	0.25
Blue Marble Cocktails	1	0.20
Indiana Whiskey	2	0.13
NouvEau	1	0.01
DSTest Laboratories	1	Accelerator
JUA Technologies International	1	Accelerator
Indiana Total, 2015-2019	66	69.01

Source: TEconomy analysis of Pitchbook venture financing database.

