

# Innovative Agbioscience in Indiana:

## 2022 ASSESSMENT



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# EXECUTIVE SUMMARY

Agricultural biotechnology innovation, also known as agbioscience innovation, is an important economic driver for the State of Indiana. Agbioscience innovation serves as an economic engine in the following ways:

- **Increasing food security/crop productivity:** agbioscience innovation can increase crop yields and reduce crop losses due to pests, diseases, and environmental stresses. This increased productivity can lead to higher profits for farmers, lower food prices for consumers, and increased food security.
- **Development of new products:** new products and processes can create new markets and industries, leading to job creation and economic growth.
- **Increasing resiliency/sustainability:** reducing the use of resources and production inputs, such as water, land, and fertilizers, makes agriculture more sustainable and efficient. This can lead to cost savings for farmers and businesses and can also help reduce environmental impact.
- **Adapting to climate change:** agbioscience innovation can help to develop crops that are more resilient to climate change, as well as practices that reduce greenhouse gas emissions. This is critical for ensuring the sustainability of agriculture in the face of changing environmental conditions.
- **Improving food quality:** agbioscience innovation can contribute to improved public health/nutrition by developing not only foods products but also crops that are more nutritious and have better taste and texture, as well as by reducing the use of unhealthy ingredients in our manufactured foods as well as harmful chemicals in agricultural production.
- **Improving global trade/market position:** agbioscience innovation can help states and regions become more globally competitive by improving their products and processes leading to competitive advantage.

Overall, agbioscience innovation drives economic growth by increasing productivity, efficiency, and competitiveness – creating pathways to new products, processes, and novel entrepreneurial business ventures. The net results are job creation, economic opportunity, and wealth creation within the Indiana economy.

In a 2014 report, *Innovative Agbioscience in Indiana: A Baseline Assessment* (reconfirmed in a 2020 update), it was found that the agbiosciences represents a cluster of Indiana economic activity rooted in established and emerging strengths associated with large-scale market opportunities. This 2023 analysis finds that the agbiosciences continue to represent a critical 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).

**Figure ES-1:** Indiana Agbioscience Innovation Platforms



Source: TEconomy Partners, LLC.

Each of these innovation platforms contributes to Indiana’s economy through distinctive scientific and technological activities:

- **Value-Added Food and Nutrition**—works to add value to basic agricultural commodities by changing or transforming a product from its original state to a more valuable, further-processed product. 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**—enhances the productivity of production agriculture by creating crops with higher yields, resistance to abiotic 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**—innovating specialized equipment and systems 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 and feed products and the therapeutics and diagnostics required to maintain the health and productivity of livestock and poultry, as well as the health and well-being of companion animals.

Within Indiana, the companies engaged in the four innovation platforms, along with the agricultural production and distribution sectors, represent a sizeable component of the state’s economy. Total agbioscience employment in Indiana reached 156,537 workers (and proprietors) in 2021. Notably, even as industries, states, and the nation overall wrestled with the employment and economic disruptions of the COVID-19 pandemic, the agbioscience sector of the Indiana economy grew. **The sector increased employment by 7.5 percent since 2018, and by more than 12.8 percent since 2012. This considerably eclipses the 2.4 percent gain in total Indiana private sector employment from 2018 to 2021** (Table ES-1).

**Table ES-1: Employment and Employment Growth of Indiana’s Agbioscience Platforms (2012–2021)**

Innovation Platform	Employment				% Employment Change			
	2012	2015	2018	2021	2012– 2015	2015– 2018	2018– 2021	2012– 2021
Agricultural Production and Distribution	69,457	70,357	69,431	74,068	1.3%	-1.3%	6.7%	6.6%
Value-Added Food and Nutrition	46,737	50,611	53,393	57,918	8.3%	5.5%	8.5%	23.9%
Plant Science and Crop Protection	7,799	7,548	6,013	6,982	-3.2%	-20.3%	16.1%	-10.5%
Agricultural Equipment, Technologies, and Systems	5,189	5,756	5,474	5,658	10.9%	-4.9%	3.7%	9.0%
Animal Health and Nutrition	9,531	10,030	11,305	12,668	5.2%	12.7%	12.1%	32.9%
<b>Total Indiana Agbioscience Industry</b>	<b>138,713</b>	<b>144,302</b>	<b>145,616</b>	<b>156,537</b>	<b>4.0%</b>	<b>0.9%</b>	<b>7.5%</b>	<b>12.9%</b>

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model. Note: columns will not sum due to eliminating cross-platform duplication.

It is important to note that employment tells only one side of the story of economic impact. With increasing global pressures and competition, the economic output of Indiana’s agbioscience industry is also a particularly important 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 four periods in 2021 dollars to better understand the real (versus inflationary) change over time. **Among the Indiana platforms, all five exhibited “real” output growth over the 2018–2021 period, with three platforms exhibiting “real” double-digit output growth.** Furthermore, over the entire 2012–2021 period, four platforms experienced “real” double-digit output growth.

**Table ES-2:** Estimated Output and Real Change in Output of Indiana’s Agbioscience Platforms (2012–2021)

Innovation Platform	Output (in 2021 dollars; \$M)				% Real Output Change			
	2012	2015	2018	2021	2012– 2015	2015– 2018	2018– 2021	2012– 2021
Agricultural Production and Distribution	\$12,700.0	\$12,379.9	\$13,210.1	\$17,061.7	-2.5%	6.7%	29.2%	34.3%
Value-Added Food and Nutrition	\$26,071.9	\$28,575.9	\$29,458.1	\$29,963.1	9.6%	3.1%	1.7%	14.9%
Plant Science and Crop Protection	\$5,507.6	\$5,502.8	\$3,104.5	\$3,329.5	-0.1%	-43.6%	7.2%	-39.5%
Agricultural Equipment, Technologies, and Systems	\$1,638.6	\$2,045.9	\$1,895.0	\$2,214.2	24.9%	-7.4%	16.8%	35.1%
Animal Health and Nutrition	\$4,008.8	\$4,085.9	\$4,353.6	\$5,541.3	1.9%	6.6%	27.3%	38.2%
<b>Total Indiana Agbioscience Industry</b>	<b>\$49,926.9</b>	<b>\$52,590.3</b>	<b>\$52,021.2</b>	<b>\$58,104.4</b>	<b>5.3%</b>	<b>-1.1%</b>	<b>11.7%</b>	<b>16.4%</b>

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model. Note: columns will not sum due to eliminating cross-platform duplication.

AgriNovus Indiana focuses its efforts on working with partners across the state to create the conditions necessary to fuel growth in Indiana’s agbioscience economy, ensuring its long-term sustainability and global competitiveness. While the input/output models allow for 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 importance of Indiana’s innovative agbioscience platforms to the state’s economy, both directly and through the multiplier effect, showing its impact on other industry sectors in Indiana as well. **Taken together, the agbioscience sector contributes more than \$91 billion in total economic impact in the State of Indiana in 2021** compared to \$76 billion in 2018. In terms of the agbiosciences’ contribution to the gross state product (GSP) of Indiana, the industry accounts for over \$19 billion in direct contribution and ultimately supports over \$37 billion in GSP. These figures represent 5 percent and 9 percent, respectively, of Indiana’s total GSP.



**Table ES-3: Economic Impact of Indiana’s Total Agbioscience Industry (2021)**

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	Local/County Tax Revenue (\$M)	State Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	156,537	\$10,644.31	\$19,397.50	\$58,104.37	\$265.97	\$736.23	\$2,031.96
Indirect Effect	83,142	\$6,177.06	\$9,509.78	\$18,624.94	\$168.43	\$417.54	\$1,088.30
Induced Effect	88,280	\$4,929.89	\$8,464.76	\$14,653.92	\$295.75	\$610.30	\$613.39
Total Impact	327,958	\$21,751.26	\$37,372.04	\$91,383.23	\$730.15	\$1,764.07	\$3,733.65
Multiplier	2.10	2.04	1.93	1.57			

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model.

Note: columns may not sum due to rounding.

Note: For more information on input-output analysis and the measures derived from the IMPLAN model, see “Overview of Input-Output Analysis” text box on page 73 of the main report.

The impact of the agbiosciences on Indiana’s economy reflects the important role of AgriNovus Indiana as a signature economic development initiative. Indiana is experiencing agbioscience-based economic growth in all four of its targeted agbioscience platforms and all appear well-positioned for future growth driven by innovation. This is evidenced, in part, by several recent major agbioscience-related economic development announcements, which include:

- Elanco’s development plan in downtown Indianapolis as its global headquarters. The planned 220,000 square-foot six-story office structure and connected innovation and collaboration buildings are designed to serve as the foundation of a planned animal health epicenter in Indianapolis.
- Corteva’s announcement that Indianapolis is the site of its new global headquarters.
- Inari raising another round of funding, bringing the company’s total cumulative equity raised to \$475 million enabling the company to further advance its position and footprint in the state.
- Taranis’ decision to locate its global headquarters in Westfield, Indiana and closing on its latest funding round, bringing the company’s total cumulative equity raised to \$99.6 million.
- Microbiome startup BiomEdit, a spinout of Elanco, raising a \$40 million Series A and locating its operation in Indiana.

Indiana’s scientists, technologists, and engineers are on the frontlines working 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

## Agbioscience Innovation—An Ongoing Development Opportunity for Indiana

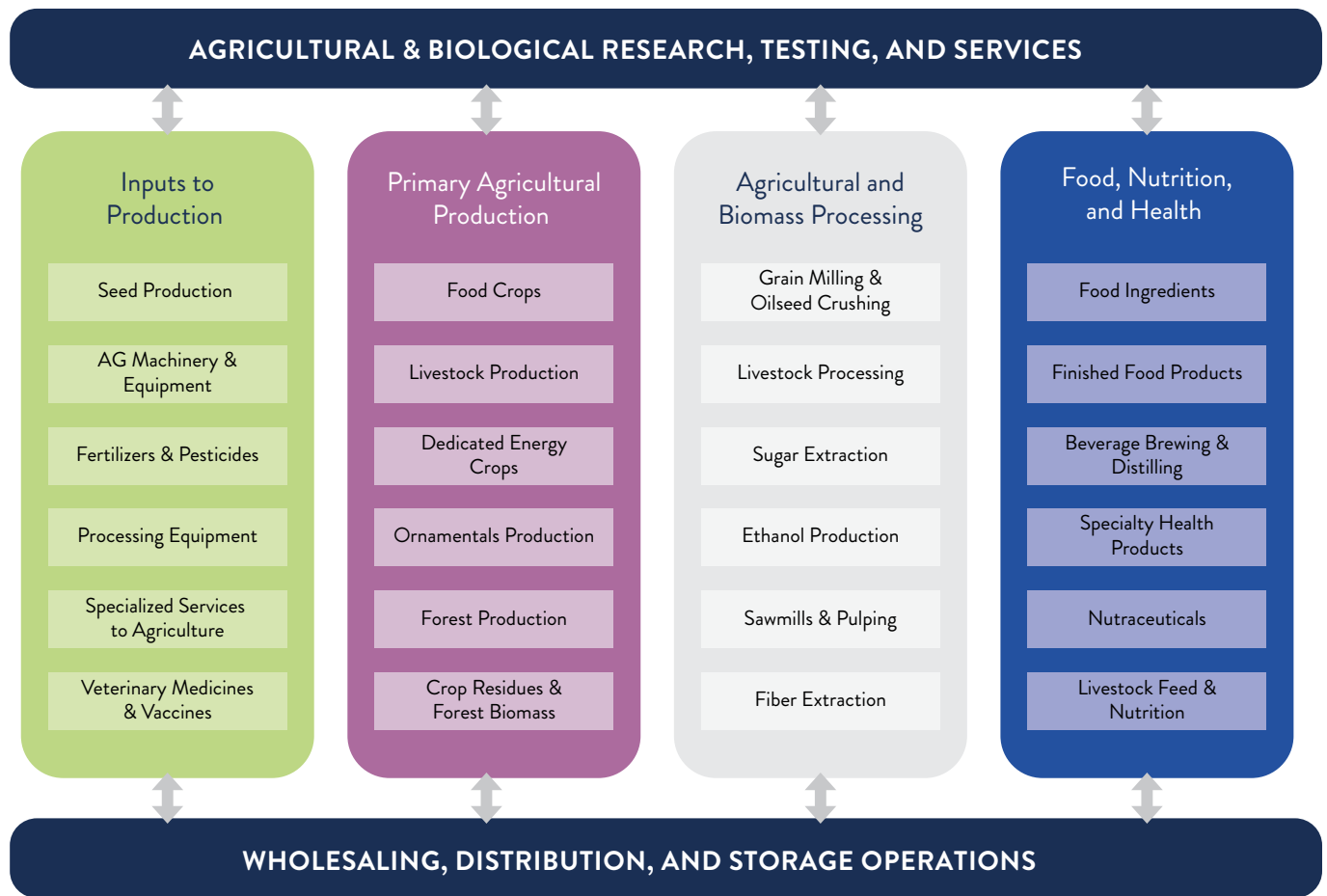
Agricultural biotechnology innovation, also known as agbioscience innovation, is an important economic driver for the State of Indiana. Agbioscience innovation serves as an economic engine in the following ways:

- **Increasing food security/crop productivity:** agbioscience innovation can increase crop yields and reduce crop losses due to pests, diseases, and environmental stresses. This increased productivity can lead to higher profits for farmers, lower food prices for consumers, and increased food security.
- **Development of new products:** new products and processes can create new markets and industries, leading to job creation and economic growth.
- **Increasing resiliency/sustainability:** reducing the use of resources and production inputs, such as water, land, and fertilizers, makes agriculture more sustainable and efficient. This can lead to cost savings for farmers and businesses and can also help reduce environmental impact.
- **Adapting to climate change:** agbioscience innovation can help to develop crops that are more resilient to climate change, as well as practices that reduce greenhouse gas emissions. This is critical for ensuring the sustainability of agriculture in the face of changing environmental conditions.
- **Improving food quality:** agbioscience innovation can contribute to improved public health/nutrition by developing not only food products but also crops that are more nutritious and have better taste and texture, as well as by reducing the use of unhealthy ingredients in our manufactured foods as well as harmful chemicals in agricultural production.
- **Improving global trade/market position:** agbioscience innovation can help states and regions become more globally competitive by improving their products and processes leading to competitive advantage.

Overall, agbioscience innovation drives economic growth by increasing productivity, efficiency, and competitiveness leading to job creation, higher profits, and economic opportunity by creating pathways to new products, processes, and novel entrepreneurial business ventures.

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

**Figure 1:** Key Components of the Agbioscience Value Chain



Source: TEconomy Partners, LLC.

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 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 Indiana led by Purdue University.
- Indiana is a hub of agbioscience activity. The agbioscience sector in Indiana is comprised of a robust ecosystem of innovative agbioscience companies and research assets.
- 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 tend 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 areas.

## Study Intent/Purpose

In 2014, the Battelle Technology Partnership Practice (now TEconomy Partners, LLC) completed a report titled “*Innovative Agbioscience in Indiana: A Baseline Assessment*.” This was a foundational report for the consideration of agbioscience as a focused innovation cluster for Indiana’s ongoing economic development and provided the initial strategic guidance for the development, mission objectives, and initial programming of AgriNovus Indiana.

In 2020, TEconomy Partners, LLC (TEconomy) updated the baseline assessment to capture the economic activity that had occurred within Indiana’s agbioscience sector between 2015 and 2018. The report found that the agbiosciences continue to represent an extremely important component of Indiana’s economy driven by an R&D ecosystem comprising both university and industrial R&D operations. The four innovation-based platforms that were identified in the 2015 analysis were confirmed to still be major drivers of innovation. The study also expanded its analysis to more deeply understand the economic importance/ impact of Indiana’s innovative agbioscience platforms.

Today, AgriNovus Indiana is working 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 has access to the specialized resources it requires for growth (in terms of skilled personnel, capital, infrastructure, facilities, etc.).

With a continued evolving mix of developments impacting Indiana’s agbioscience sector, AgriNovus Indiana determined it to be prudent to perform an update to the 2015 and 2020 analyses to determine the progress that has occurred and the ongoing promise of the agbiosciences as an economic driver for Indiana moving forward. This report performs these analyses, providing an in-depth assessment of progress made and opportunities for the future.

The structure of this report is similar to the prior studies:

- **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 A.
- **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, intellectual property (IP) generation, and the level of graduate output in agbioscience and associated disciplines in Indiana.
- **Chapter IV provides an assessment of the performance across designated innovative “development platforms.”** The platforms are once again confirmed as areas of significant strength and competitive advantage and then further defined and examined.
- **Chapter V provides an 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 summarizes conclusions** based on the full findings of the 2022 project.

# CHAPTER II. INDIANA’S AGBIOSCIENCE PROFILE

## Introduction—Data and Methodology

The following economic analysis examines Indiana’s agbioscience industry employment composition from 2018–2021 (with 2021 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 almost exclusively on the NAICS.<sup>1</sup>

For this NAICS-based employment analysis, TEconomy uses the 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. 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.<sup>2</sup> TEconomy utilizes an “enhanced” version of these state and county data purchased from Lightcast, a private vendor, which provides some estimated data when specific information does not meet federal data disclosure rules.

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 does not cover self-employed farmers, sole proprietors, 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 employees 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 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 to provide a detailed overview of the entire agricultural production industry in Indiana.

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1 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 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 A.

2 Major exclusions from UI coverage, and thus from the QCEW data, includes: 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.

## Size and Performance of Indiana's Agbioscience Industry

Table 1 provides comparative data for 2018 and 2021, both for the agbioscience sector as defined overall and for its primary segments and subsectors.

**For the agbiosciences overall, Indiana employment grew by 3,373 jobs from 2018–2021, expanding from 141,870 jobs in 2018 to 145,243 jobs in 2021 (an increase of 2.4 percent). These figures include on-farm employment (farm proprietors within Primary Production). Considering the seemingly continual decline in farm proprietors, when excluding this subsector, employment growth across the remaining agbioscience segments shows an even larger increase of 4.6 percent or 4,248 jobs.**

In both cases, Indiana's growth in agbioscience employment from 2018–2021 exceeded national growth levels, 2.9 percent above in industry corporate-based employment growth (not including farm proprietors) and 1.4 percent in total employment growth (including farm proprietors).

The agbioscience cluster overall represents a higher-paying cluster in comparison with average private-sector wages in Indiana. The average wage of \$69,368 in the total agbioscience cluster (not including farm proprietors) in 2021 is 3.03 percent higher than the average private-sector wage of \$67,328 in the state.

## 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 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 reasons:

1. Employment estimates in Chapter V also include small numbers of proprietors in sectors beyond primary production.
2. Employment estimates in Chapter V 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 in Chapter V 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	2021 Metrics				2018 Metrics		Recent Indiana Employment Performance	Recent U.S. Employment Performance	Recent Indiana Relative Employment Performance
	Estabs.	Employ.	Avg. Wage	Specialization (LQ)	Estabs.	Employ.	“Change, 2018-2021”	“Change, 2018-2021”	
<b>Ag/Bio Research, Testing, &amp; Services</b>	696	9,384	\$49,932	0.93	690	8,545	9.8%	12.6%	-2.7%
Research & Development (Ag/Bio/Food)	6	43	\$127,298	0.25	4	48	-9.3%	23.3%	-32.6%
Testing Laboratories (Ag/Bio/Food)	31	370	\$77,481	0.80	28	412	-10.1%	1.3%	-11.4%
Veterinary Services	659	8,971	\$48,422	0.95	658	8,085	11.0%	13.0%	-2.0%
<b>Inputs to Production</b>	894	12,088	\$93,430	1.55	852	12,044	0.4%	1.2%	-0.9%
Ag Machinery & Equipment	392	5,912	\$78,402	1.39	378	5,893	0.3%	1.5%	-1.1%
Agricultural Chemicals**	41	1,031	\$105,579	1.28	33	1,022	0.9%	5.4%	-4.5%
Agricultural Inputs Wholesaling	458	4,111	\$83,879	1.64	438	4,312	-4.6%	-1.1%	-3.6%
Veterinary Medicines & Vaccines	4	1,034	\$205,258	4.36	3	817	26.4%	8.8%	17.6%
<b>Primary Production (Corp + Proprietors)</b>	55,100	63,977	N/A	0.99	56,100	64,389	-0.6%	-1.3%	0.7%
Agricultural & Biomass Production	1,376	8,494	\$55,412	0.42	1,285	8,027	5.8%	-1.6%	7.5%
Livestock Production	655	7,245	\$52,762	1.15	605	7,249	0.0%	-0.4%	0.3%
Farm Proprietors*	53,069	48,238	N/A	1.26	54,210	49,113	-1.8%	-0.8%	-0.9%
<b>Agricultural &amp; Biomass Processing</b>	136	4,719	\$86,554	1.30	143	4,853	-2.8%	-1.7%	-1.1%
Agricultural Processing	32	2,968	\$94,870	1.84	30	2,931	1.3%	1.8%	-0.6%
Biomass Processing	104	1,751	\$72,457	0.87	113	1,922	-8.9%	-4.3%	-4.6%
<b>Food, Nutrition, &amp; Health</b>	891	48,543	\$70,941	1.16	772	45,423	6.9%	3.4%	3.5%
Beverage Manufacturing	236	6,601	\$61,311	1.06	200	5,857	12.7%	9.7%	3.0%
Drugs & Diagnostics	35	3,226	\$182,865	1.34	23	3,185	1.3%	21.8%	-20.5%
Food Processing & Manufacturing	620	38,716	\$63,258	1.16	550	36,380	6.4%	1.2%	5.2%
<b>Wholesaling, Distribution, &amp; Storage Operations</b>	384	6,532	\$62,728	0.95	356	6,616	-1.3%	-7.4%	6.1%
Agricultural Commodity Wholesaling	199	2,045	\$65,366	1.41	187	2,125	-3.8%	-5.3%	1.5%
Food Product Wholesaling	145	2,211	\$68,233	0.58	133	2,385	-7.3%	-11.9%	4.6%
Warehousing and Storage	41	2,276	\$55,010	1.38	36	2,106	8.1%	2.7%	5.3%
<b>State of Indiana AgBio Industry Corporate Only Total</b>	5,032	97,005	\$69,368	1.00	4,703	92,757	4.6%	1.7%	2.9%
<b>State of Indiana AgBio Industry Corporate and Proprietor Total</b>	58,101	145,243	N/A	1.07	58,913	141,870	2.4%	1.0%	1.4%
<b>Total Private Sector</b>	171,536	2,631,284	\$67,328	1.00	159,696	2,658,878	2.4%	-1.6%	3.9%

Source: TEconomy analysis of BLS, CEW enhanced data from Lightcast, Farm Proprietor employment data from BEA, and Farm Proprietor establishment data from USDA NASS 2021 Agricultural Survey.

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

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

As with any multi-sector analysis, individual sectors often show varying trends and details. For example, the R&D-focused segment of **Ag/Bio Research, Testing, and Services** grew employment by 9.8 percent for 2018–2021, versus 3.1 percent for 2012–2015.

The **Inputs to Production** segment recorded a slight increase in employment from 2018–2021 (reaching 12,088 jobs) after showing significant declines from 2015–2018. However, given the presence of global leaders Elanco Animal Health and Corteva Agriscience in the state, TEconomy cautions that these employment figures may still undercount the employment in this segment as some or all of the employment for both of these firms may be classified in NAICS 551114 Corporate, Subsidiary, and Regional Managing Offices. With this employment increase, this segment reaches a location quotient of 1.55—the most specialized agbioscience segment in Indiana.<sup>3</sup>

**Primary Production** shows a slight (-0.6 percent) decline in overall employment. However, this decline is driven by a loss of 875 farm proprietor jobs from 2018–2021. Corporate-based agricultural and biomass production (crop farming) actually increased by 5.8 percent or 467 workers over the period.

The **Agricultural and Biomass Processing** segment saw a 2.8 percent decline in employment between 2018 and 2021, yet with more than 4,700 employees it is the second most specialized Indiana Agbioscience segment at an LQ of 1.30.

Indiana’s **Food, Nutrition, and Health** segment saw employment growth of 6.9 percent, outpacing the U.S. growth by 3.5 percent. At over 48,500 employees this is the second largest segment after primary production, and the largest segment if farm proprietors are excluded from the analysis.<sup>4</sup>

The **Wholesaling, Distribution, and Storage Operations** segment remained fairly stable over the three years, losing only 84 jobs from 2018–2021. Indiana’s heartland geography appears to play a role in both ag commodity wholesaling (LQ=1.41) and warehousing and storage (LQ=1.38) where agricultural production and central U.S. logistics strengths appear to connect with the agbiosciences. Food product wholesale’s LQ of 0.58 likely indicates that this sector is more geared toward moving food and grocery products around to the state’s retail and consumer locations, versus performing a centralized U.S. logistics function.

Figures 2 through 5 that follow provide a further analytical perspective on the data presented in Table 1, placing segments and subsectors employment (the size of each bubble is proportionate to its 2021 employment) on quadrants measuring concentration (LQ; Y-axis) and employment growth (X-axis). Figures 2 and 3 show the growth rate at the state level and figures 4 and 5 show the growth rate relative to the U.S.

Figure 2 summarizes the 2018–2021 segment data. The importance of the Food, Nutrition, and Health segment is shown via the large segment in the upper right quadrant. Performance in this quadrant indicates a segment that is both growing since 2018 and concentrated (being above the LQ=1.00 or national average performance line). Inputs to Production is also within this quadrant but had limited growth from 2018–2021 and is about one-quarter of the employment size of Food, Nutrition, and Health.

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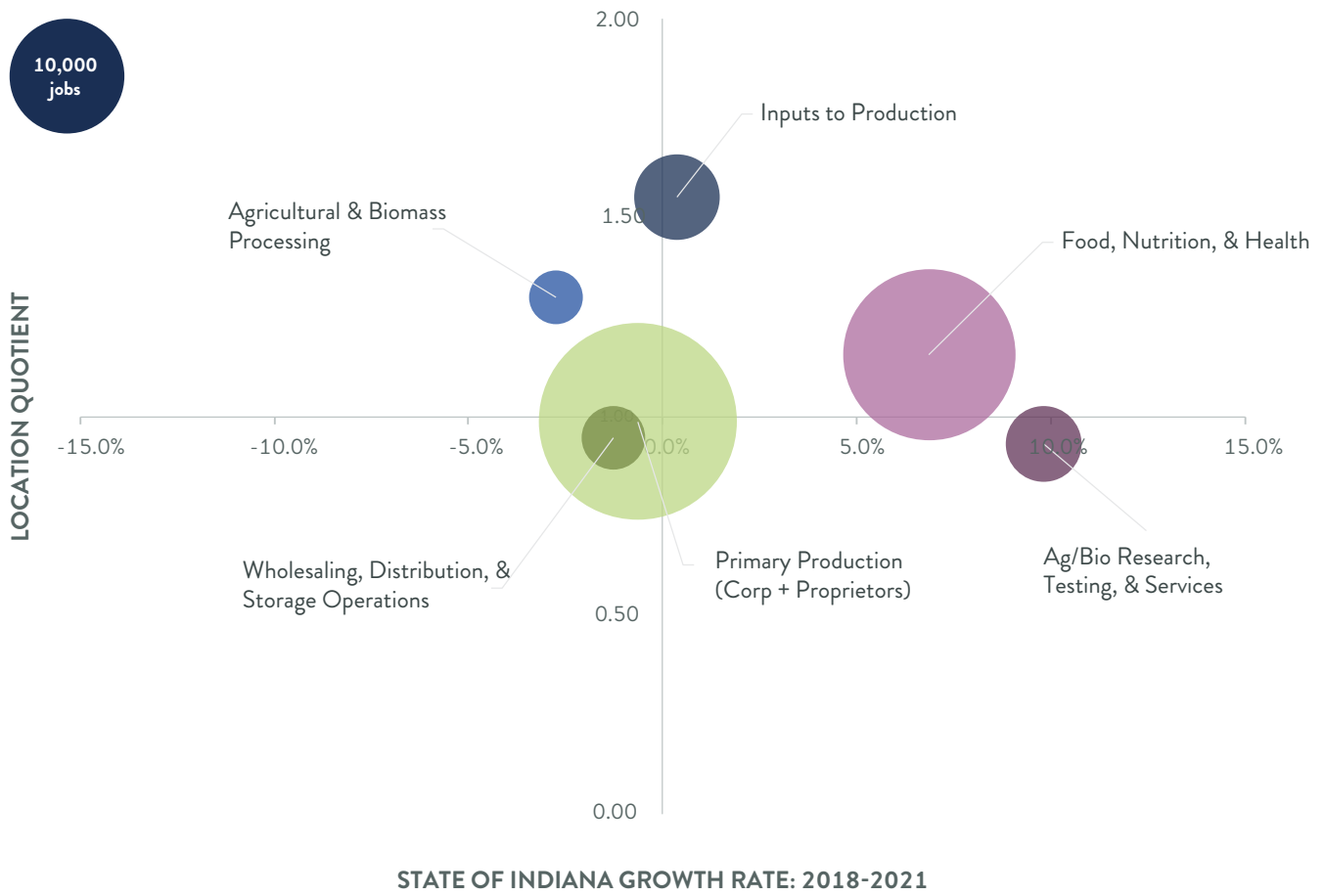
3 The location quotient (LQ) metric measures the employment concentration within state or region to gauge the relative importance of an industry to that state or region. The location quotients measure the degree of job concentration relative to the national average. States or regions with an LQ greater 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.

4 Importantly, the Drugs & Diagnostics subsector does not include any employment from NAICS 325412. This is the NAICS code in which Eli Lilly’s manufacturing operations are included. Elanco, also likely classified in part in NAICS 325412, is captured in the Veterinary Medicines and Vaccines subsector.

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**Figure 2: Indiana Agbioscience Segment Performance (2018–2021)**

*(Bubble size is proportionate to employment value)*



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

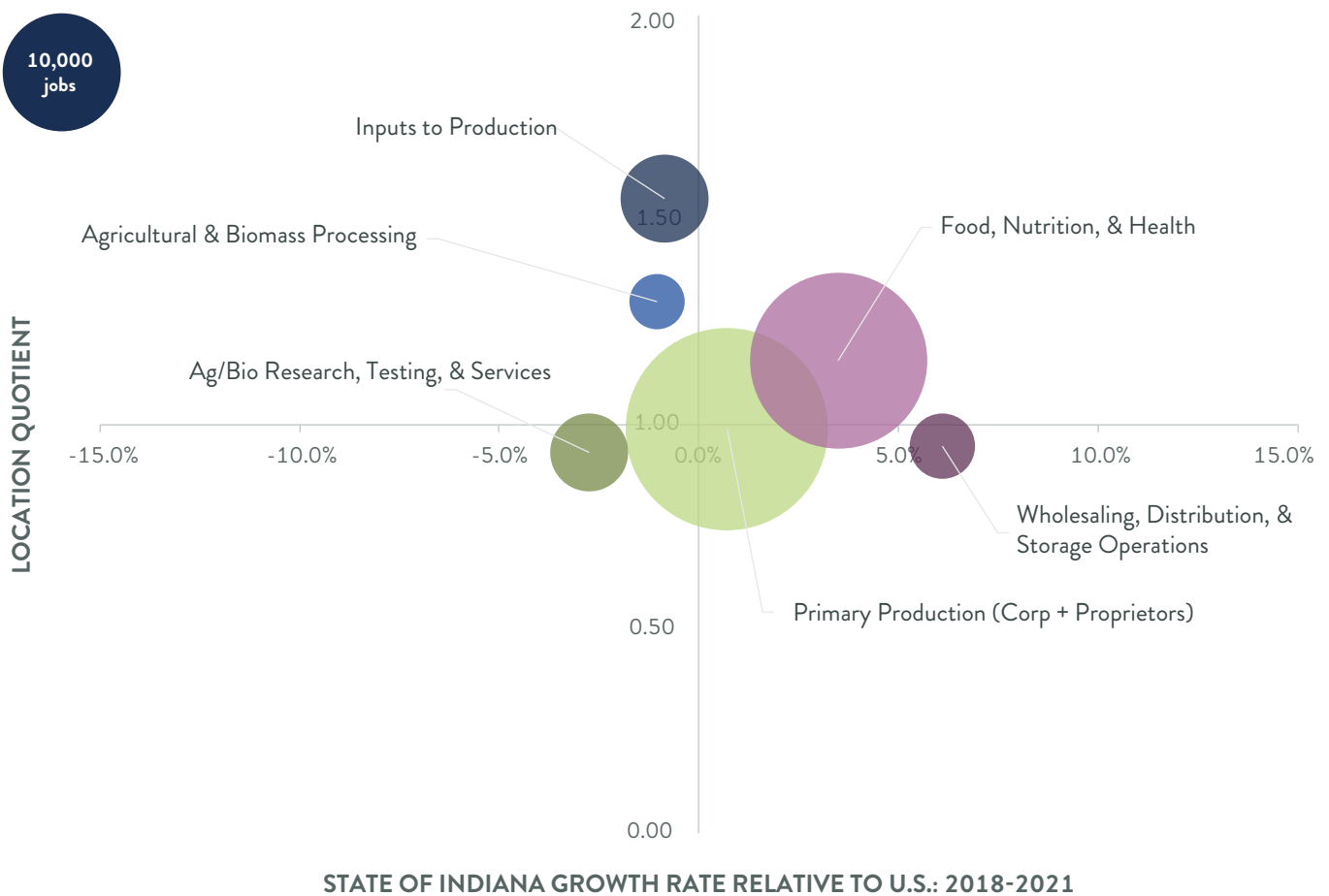


While Figures 2 and 3 show an Indiana-centric picture, Figures 4 and 5 provide a picture that portends Indiana’s agbioscience segments and subsectors competitive position.

Figure 4 shows that only one Indiana segment, Food, Nutrition, and Health, gained competitive position from 2018 to 2021, outpacing U.S. growth by 3.5 percent. This, combined with the LQ of 1.16 sets it apart as the only segment in the upper right quadrant. Two other segments, Wholesale, Distribution, and Storage Operations and Primary Production appear to show competitive growth but are declining at rates somewhat less than the nation overall (leading to a net positive relative growth rate).

**Figure 4:** Comparative Indiana Agbioscience Segment Performance (2018–2021)

*(Bubble size is proportionate to employment volume)*



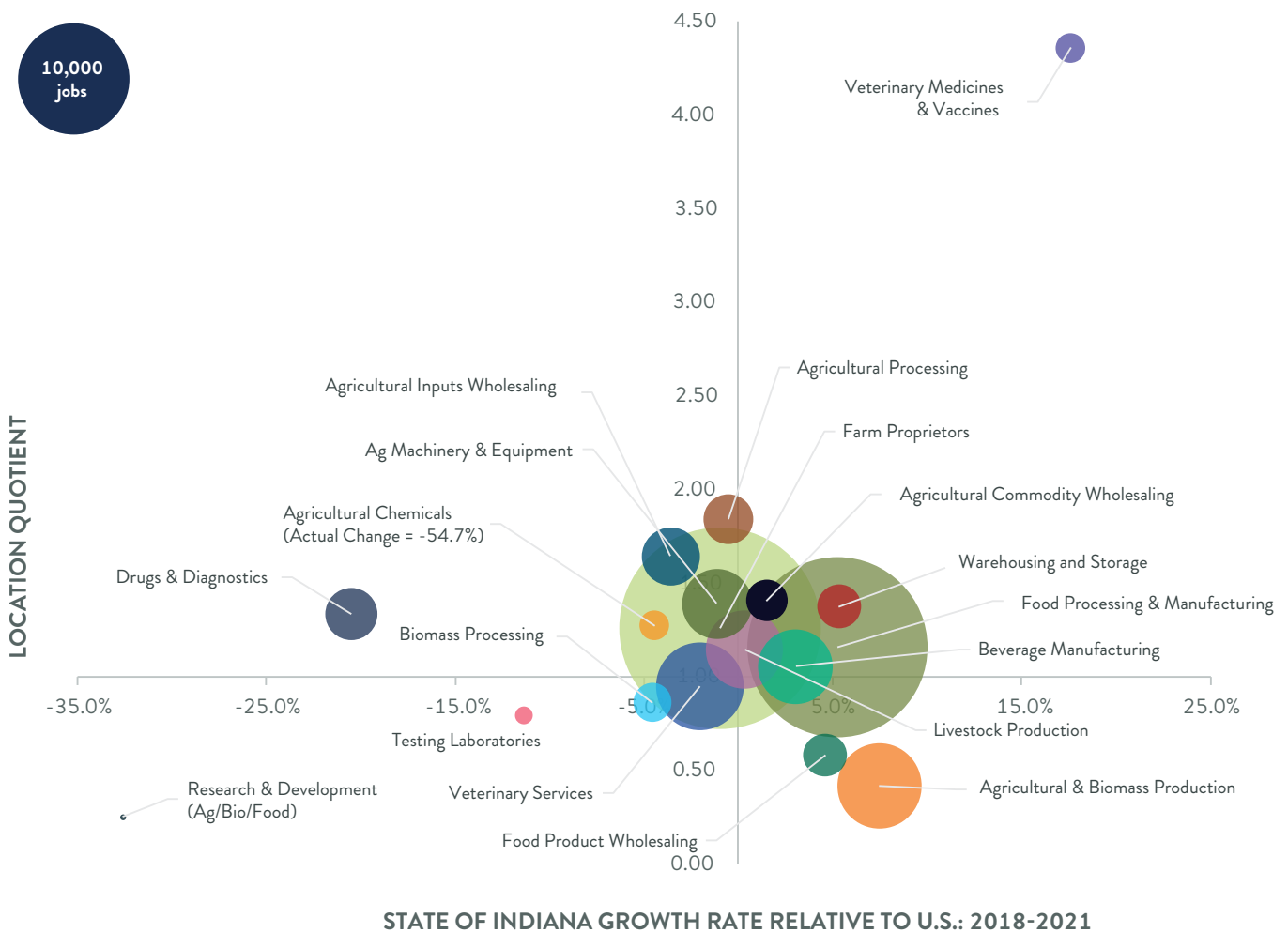
Source: TEconomy analysis of BLS, CEW enhanced data from IMPLAN, and Farm Proprietor employment data from the BEA.

When examining the data at the more detailed subsector level (Figure 5), 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, significantly outpace national growth by 5 percent or more, including:

- Veterinary Medicines and Vaccines
- Agricultural and Biomass Production
- Warehousing and Storage
- Food Processing and Manufacturing.

**Figure 5:** Comparative Indiana Agbioscience Subsector Performance (2018–2021)

*(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.

## Primary Agriculture Production in Indiana

While AgriNovus Indiana concentrates its programmatic efforts on “innovative agbiosciences,” a key driver of overall state performance is the primary agricultural sector—either as inputs to it or as processors or distributors of outputs from it. It is within this agricultural strength that Indiana’s agbioscience industry operates and is geared to support. The importance of the interrelationships among Indiana’s farmers and growers, the infrastructure to collect and distribute agricultural commodities, and the extensive variety of food and beverage processing entities to turn these agricultural commodities into higher value-added products cannot be overstated. Within this production ecosystem, Indiana is also home to significant R&D operations geared toward improving the productivity of farms across the world.

The USDA’s National Agricultural Statistics Service (NASS) reports summary data that provides a base perspective on Indiana’s overall agbioscience performance. While there is some annual fluctuation, Indiana’s total agricultural land has remained relatively stable since 2012 at about 14.8 million acres. However, similar to the U.S. overall, the number of farm operations has declined on an annual basis from 58,700 in 2012 to 55,100 in 2021. As a result, the average size of operations increased, rising from 250 acres in 2012 to 269 acres in 2021 (a 7.26 percent increase in the average number of acres operated on Indiana farms). This trend of increasing farm size is also seen nationally, though the percentage increase in Indiana is significantly larger than the nation’s 2.65 percent increase in farm size.

In terms of overall farmgate financial output (as measured by total farm receipts), it is evident that Indiana experienced a relative stabilization from 2018 to 2020, with a dramatic increase in 2021. Table 2 and Figure 6 illustrate this cash receipts trend line (as reported by USDA Economic Research Service).<sup>5</sup>

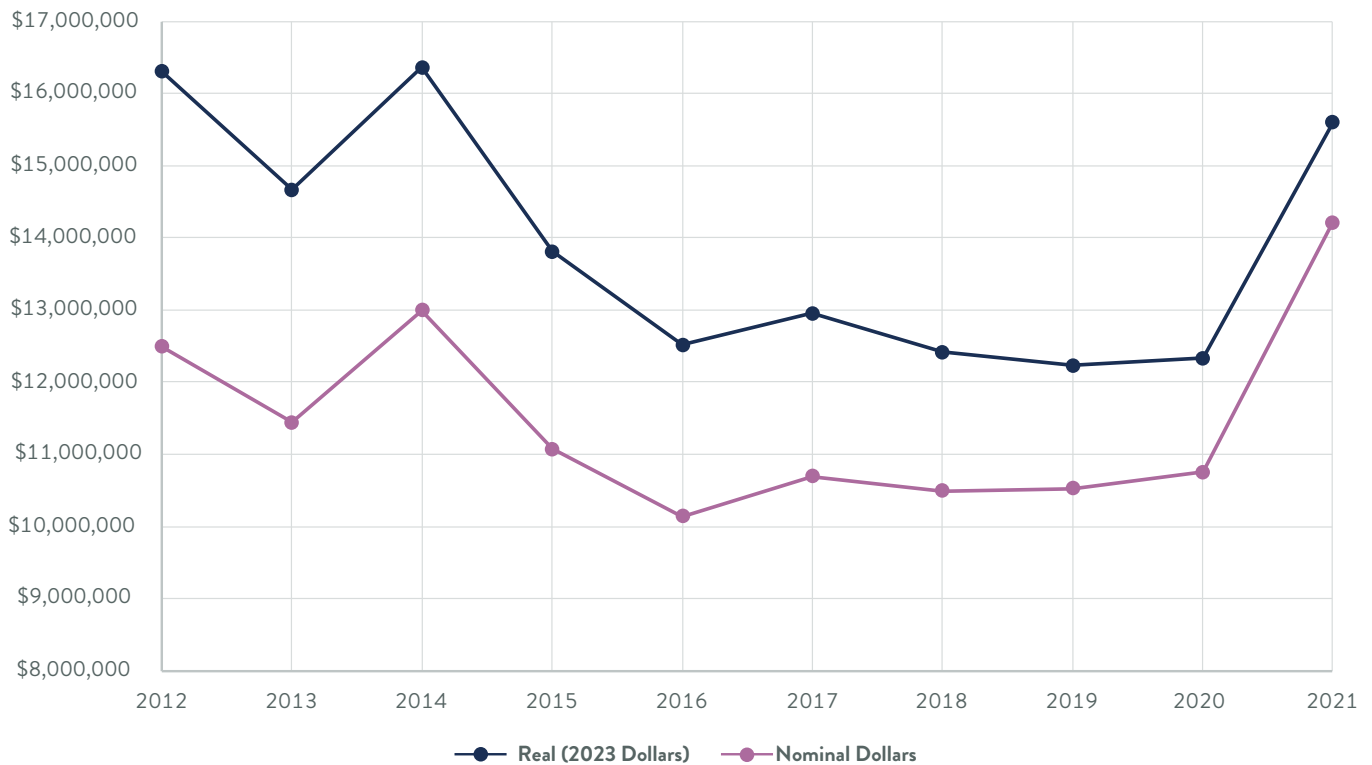
**Table 2:** Indiana Agriculture Cash Receipts for All Commodities (2012–2021, \$000s)

Year	Real (2023 Dollars)	Nominal Dollars	Percent of U.S.
2012	16,298,283	12,488,722	3.11%
2013	14,667,044	11,437,654	2.83%
2014	16,363,129	12,997,560	3.07%
2015	13,805,586	11,071,942	2.93%
2016	12,518,821	10,139,744	2.83%
2017	12,952,985	10,693,985	2.89%
2018	12,410,868	10,493,761	2.83%
2019	12,228,079	10,522,751	2.87%
2020	12,329,451	10,752,761	2.96%
2021	15,597,670	14,213,689	3.25%

Source: U.S. Department of Agriculture, Economic Research Service, Cash Receipts Data.

<sup>5</sup> Source: USDA ERS. “Farm income and wealth statistics.” “Cash receipts by commodity, 2021.” <https://data.ers.usda.gov/reports.aspx?ID=17844>.

**Figure 6:** Indiana Agriculture Cash Receipts for All Commodities (2012–2021, \$000s)



Source: TEconomy analysis of U.S. Department of Agriculture, Economic Research Service, Cash Receipts Data.

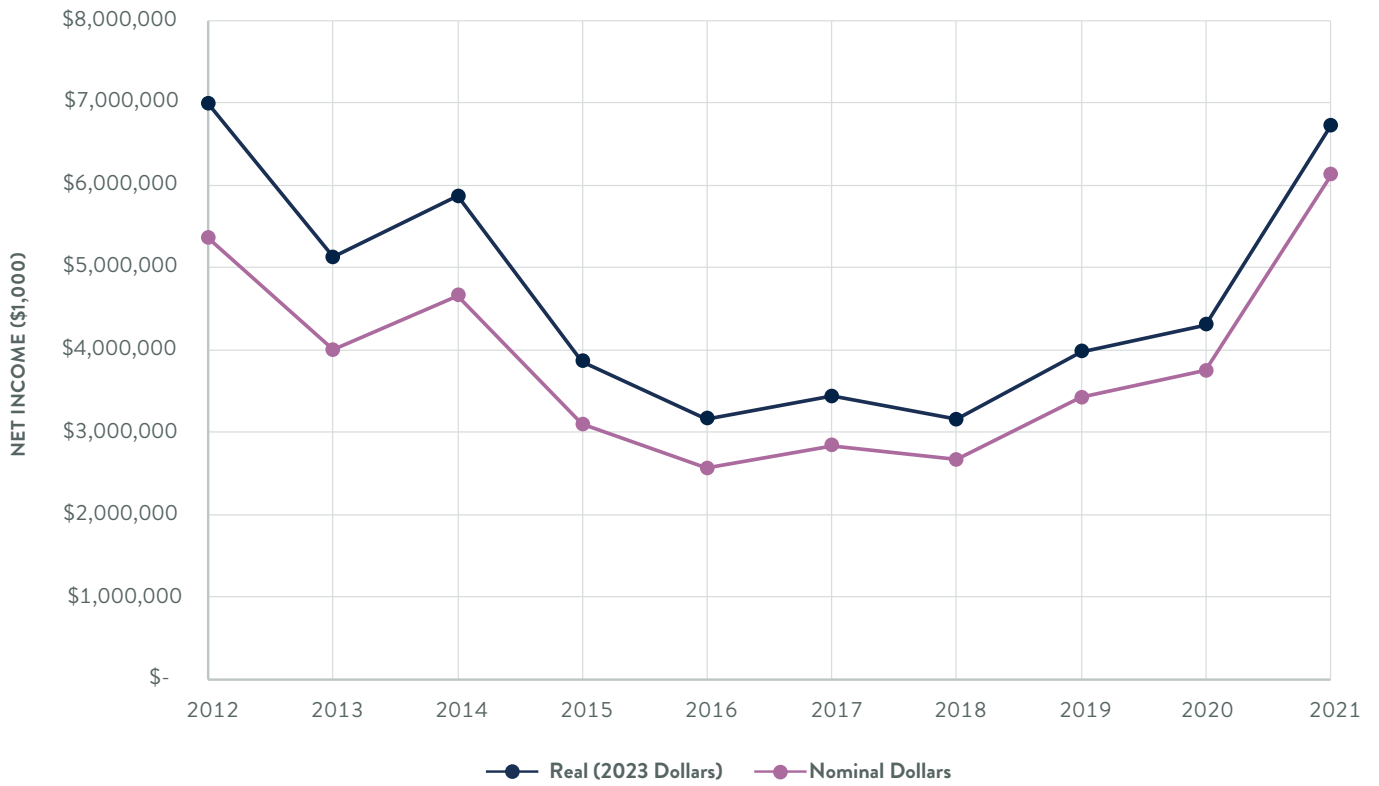
The increase in 2021 was driven primarily by a 48.4 percent real dollar increase (\$1.8 billion) in feed corn receipts from 2020-2021 likely at least somewhat associated with a 45.2 percent real dollar increase (\$535 million) in hogs' receipts.

Indiana's agriculture is only moderately diverse in terms of the crops it produces. The largest crops, by far, are corn and soybeans. Combined, Indiana's corn (feed corn) and soybean production generated \$9.0 billion in 2021, or 64 percent of Indiana's total farm receipts. Among other principal Indiana commodities, hog production generated an additional \$1.6 billion, milk and other farmgate dairy products generated nearly \$833 million, turkey production generated nearly \$687 million, and egg production generated \$603 million.

Since 2018, Indiana farmers have steadily improved their income, with the dramatic 2020-2021 increase in receipts also reflected in an increase of 57 percent in real dollar income in 2021 (Figure 7). At this level, Indiana accounted for 4.1 percent of U.S. farm net cash income, up from 2.6 percent in 2018.



**Figure 7:** Indiana Farms Net Cash Income (2012–2021, \$000s)



Source: TEconomy analysis of U.S. Department of Agriculture, Economic Research Service, Net Cash Income Data.

## Summary

The agbioscience industry continues to be a key and growing industry for Indiana. Inclusive of agricultural production, the agbioscience cluster directly employed more than 145,000 Hoosiers in 2021. While farm proprietors' employment continues to slowly decline, the "industrial" sectors and subsectors in Indiana's agbioscience industry grew by 4.6 percent, reaching 97,000 employees in 2021. When combined with primary production overall employment grew at 2.4 percent, mirroring Indiana's total private sector employment growth.

Indiana maintains industry (employment) specialization (having an LQ > 1.2) in many agbioscience segments and subsectors. Most notable is that all four subsectors included within the Inputs to Production segment are considered specializations of the state (segment LQ = 1.55).

From a job growth perspective, the Food Processing and Manufacturing subsector grew by more than 2,300 jobs from 2018–2021, an increase of 6.4 percent and outpacing growth in this subsector at the U.S. level. This job growth accounted for over half (55 percent) of the additional jobs in the Indiana agbioscience industry. Veterinary Services accounted for an additional 839 jobs over the period for a growth rate of 9.8 percent. Beverage Manufacturing also grew by 744 jobs during the period for a growth rate of 12.7 percent (also outpacing the U.S.). Veterinary Medicines and Vaccines have the largest growth rate at more than 26 percent, but due to the potential changing of some establishment classifications and the impact that may have on employment numbers, this growth rate should be viewed with some caution.

While Primary Production may be declining in terms of employment, continued productivity improvements and a strong 2021 harvest has led Indiana to its largest agricultural sales (receipts, in current \$) during the 2012-2021 period of more than \$14.2 billion in 2021. The full economic impacts of the agbiosciences and Primary Production in Indiana are explored further in Chapter V.

# CHAPTER III. INDIANA’S AGBIOSCIENCE RESEARCH AND EDUCATION 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.

The most recent National Science Foundation (NSF) higher education R&D (HERD) expenditure data showed Indiana academic institutions spending over \$123 million on agricultural sciences R&D in 2021, down 3.8 percent from 2018 (Figure 8). A general slight downward trend has taken shape from 2016-2021, except for a \$139.4 million highly funded year in 2019. In 2019, Purdue received a significant influx of more than \$15 million in funding from institutional (\$6.5 million more than in 2018), non-profit (\$3.4 million more), and all other (non-governmental and non-industry; \$5.0 million more) sources<sup>6</sup>. In fact, these “all other sources” of funding have continued at a higher level and continued to grow through 2021, partially offsetting other year-over-year declines from other sources.

**Figure 8:** Indiana Agricultural Science Academic R&D (\$M)



Source: TEconomy analysis of NSF National Center for Science & Engineering Statistics, Higher Education R&D (HERD) Survey, 2015-2021.

<sup>6</sup> These data also do not include Purdue University’s R&D efforts around agricultural engineering that cannot be distinctly split out from the HERD data’s \$52 million in the Other Engineering field.

Insights into specific areas of Indiana academic agbioscience R&D strengths may be derived from analysis of publications produced in agricultural and associated academic disciplines/fields. As with the 2018 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**—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 these three macro categories. Data are for publications in the 2018 through 2021 time frame showing the number of combined records by field for all Indiana institutions, the percent of total Indiana 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 research field where 1.0 equals parity with the nation in the discipline, and a number higher than 1.0 indicates a comparative concentration or 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.

**Table 3: Agbioscience and Associated/Ancillary Academic Research Fields—Indiana Publications for 2018–2021.**

Macro Category	Web of Science Field	Indiana Number of Pubs Records, 2018–2021	Percent of All IN Pubs Records, 2018–2021	U.S. Number of Pubs Records, 2018–2021	Publication Quotient, 2018–2021
Principal Agriculture and Agbioscience Fields	Plant Sciences	802	1.34	22,316	1.18
	Food Science Technology	641	1.07	17,549	1.20
	Veterinary Sciences	604	1.01	17,222	1.16
	Agriculture & Dairy Animal Science	429	0.72	7,421	1.91
	Agronomy	382	0.64	10,198	1.24
	Entomology	266	0.45	8,822	0.99
	Forestry	214	0.36	6,549	1.08
	Agricultural Economics & Policy	161	0.27	2,167	2.45
	Agriculture - Multidisciplinary	136	0.23	3,711	1.21
	Soil Science	132	0.22	4,181	1.04
	Horticulture	89	0.15	3,787	0.77
	Agricultural Engineering	84	0.14	2,397	1.16
Mycology	82	0.14	1,672	1.62	

Macro Category	Web of Science Field	Indiana Number of Pubs Records, 2018–2021	Percent of All IN Pubs Records, 2018–2021	U.S. Number of Pubs Records, 2018–2021	Publication Quotient, 2018–2021
Related Basic Research Fields	Biochemistry & Molecular Biology	1,839	3.08	70,165	0.86
	Ecology	975	1.63	33,951	0.95
	Cell Biology	936	1.57	42,669	0.72
	Genetics & Heredity	931	1.56	31,488	0.97
	Microbiology	728	1.22	31,695	0.76
	Immunology	665	1.11	40,026	0.55
	Biotechnology & Applied Microbiology	656	1.10	22,947	0.94
	Biology	535	0.90	21,129	0.83
	Zoology	430	0.72	15,833	0.90
	Chemistry - Organic	427	0.72	9,244	1.52
	Evolutionary Biology	404	0.68	11,872	1.12
	Biophysics	317	0.53	12,226	0.85
	Parasitology	217	0.36	7,144	1.00
	Virology	205	0.34	10,668	0.63
Ancillary or Related Application Fields	Multidisciplinary Sciences	2,341	3.92	83,755	0.92
	Environmental Sciences	2,072	3.47	72,770	0.94
	Energy & Fuels	902	1.51	36,422	0.82
	Chemical Engineering	765	1.28	21,980	1.15
	Water Resources	582	0.98	16,913	1.13
	Infectious Diseases	567	0.95	25,642	0.73
	Nutrition & Dietetics	555	0.93	16,951	1.08
	Meteorology & Atmospheric Sciences	535	0.90	21,436	0.82
	Environmental Engineering	533	0.89	15,575	1.13
	Green/Sustainable Science & Technology	455	0.76	15,451	0.97
	Remote Sensing	334	0.56	12,072	0.91
	Chemistry - Applied	320	0.54	7,545	1.40
	Environmental Studies	279	0.47	10,851	0.85
	Materials Science - Biomaterials	204	0.34	8,233	0.82
	Limnology	133	0.22	3,372	1.30
	Materials Science - Paper & Wood	24	0.04	1,028	0.77

Source: TEconomy analysis of Web of Science data.

Note: Some journals and publications can be mapped by Web of Science into more than one field. Numbers cannot be summed.

In the first category of Principal Agriculture and Agbioscience Fields, Indiana generated 4,022 publications from 2018 through 2021 with the top fields being Plant Sciences (802), Food Science Technology (641), and Veterinary Sciences (604). It should be noted that publications in academic journals are not the exclusive domain of academic scientists. Indeed, companies in Indiana, such as Corteva, Reckitt Benckiser (Mead Johnson Nutrition), and Elanco, 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 indicated by bold numbers 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 (ranked by the number of publications):

- **Plant Sciences**, 802 publications (PQ = 1.18)
- **Food Science Technology**, 641 publications (1.20)
- **Veterinary Sciences**, 604 publications (1.16)
- **Agriculture Dairy Animal Science**, 429 publications (1.91)
- **Agronomy**, 382 publications (1.24)
- **Agricultural Economics Policy**, 161 publications (2.45)
- **Agriculture Multidisciplinary**, 136 publications (1.21)
- **Agricultural Engineering**, 84 publications (1.16)
- **Mycology**, 82 publications (1.62)

It is important to note that in the Principal Agriculture and Agbioscience Fields macro category, Indiana has a comparative specialization (PQ > 1.10) in all fields except for Entomology, Forestry, and Horticulture (whose level of specialization had been increasing). Also of note is that Agricultural Engineering’s PQ continues to increase, reaching 1.16 in this current analysis, indicating that it is an important part of the “Other Engineering” research performed in the state.

In the Related Basic Research Fields examined for this effort, Indiana has a below-average concentration in all the listed disciplines except two—**Organic Chemistry** (427 publications and a PQ of 1.52) and **Evolutionary Biology** (404 publications and a PQ of 1.12).

In the more peripherally related Ancillary or Related Application Fields category, beyond an overall increase in the number of publications produced in these fields, specializations for Indiana are evident in the following:

- Fields associated with **chemistry**, including Chemistry-Applied (320 publications and 1.40 PQ) and Chemical Engineering (765 publications and a 1.15 PQ).
- Fields associated with **water**, including Water Resources (582 publications, PQ = 1.13) and Limnology (133 publications, PQ = 1.30).
- **Environmental Engineering** is also a current specialization (533 publications, PQ = 1.13).

Infectious diseases and associated pathogen biology continues to be a broad area where Indiana may have a comparative weakness (as measured by low PQ in related disciplines). Indiana continues to have below average PQs in Immunology (0.55), Virology (0.63), and Infectious Diseases (0.73).

## Agbioscience Industrial Research & Development in Indiana

Fully understanding the size and scope of Indiana’s agbioscience-related industrial R&D requires an examination of a variety of federally collected data and statistics.

As shown in Table 4, Indiana Food Industry R&D reached a significant, all-time high in 2020 with \$259 million as captured in the NSF Business and R&D survey. Additional R&D performed in ag chemicals and ag machinery industries add an additional \$5 million. These agbioscience sectors combine for \$264 million or 3.67 percent of all Indiana industrial R&D reported in the 2020 NSF survey.

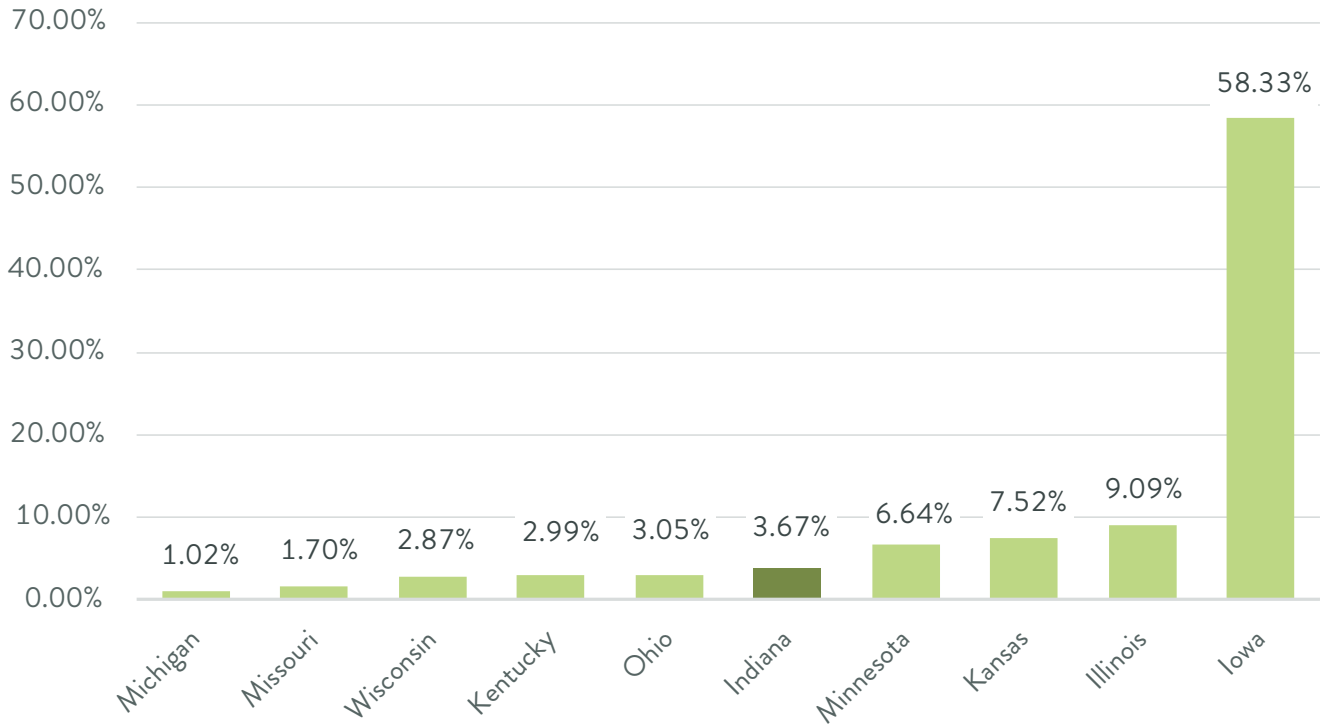
**Table 4:** Indiana Agbioscience Industry R&D, 2015-2020, \$ millions

Industry Sector	2015	2016	2017	2018	2019	2020
Food Manufacturing	\$85	\$93	\$82	\$28	\$35	\$259
Pesticides, fertilizer, and other agricultural chemicals	Non-Disclosed	Non-Disclosed	\$8	\$3	\$10	\$2
Agricultural Machinery & Implements	\$7	\$3	\$5	\$7	\$5	\$3
Total	\$92	\$96	\$95	\$38	\$50	\$264
Share of Indiana’s Total Industry R&D	1.72%	1.92%	1.76%	0.63%	0.73%	3.67%

Source: TEconomy analysis of NSF National Center for Science & Engineering Statistics, Business, and Enterprise R&D (BERD) Survey, R&D Paid for and Performed by Company, 2015-2020 (most recent year available).

Comparatively, Indiana’s 3.67 percent share of total industrial R&D falls in the middle of regional competitors, especially among those with a diversified economy (Figure 9).

**Figure 9:** Agbioscience Share of Total Industrial R&D, 2020 (Selected States)



Source: TEconomy analysis of NSF National Center for Science & Engineering Statistics, Business, and Enterprise R&D (BERD) Survey, R&D Paid for and Performed by Company, 2015-2020 (most recent year available).

**This 3.67 percent for Indiana, however, does not tell the whole agbioscience story. At least two significant firms are likely outside of this tabulation.** First, Elanco Animal Health is captured within the NAICS 3254 Pharmaceutical Manufacturing. Given the presence of Eli Lilly & Company and other pharmaceutical manufacturers in the state, that sector’s R&D is not incorporated into the Agbioscience numbers presented in Table 4. However, to provide comparative context, Elanco’s corporate-wide R&D, since it became a standalone corporate entity reached \$246.6, \$270.1, and \$327.0 million, in 2018, 2019, and 2020, respectively.<sup>7</sup> Given Elanco’s substantial R&D presence in Indiana and its significant North American sales, it is likely that a majority of this R&D is performed in Indiana. Second, Corteva also performs a significant amount of R&D reaching \$1.355 billion in 2018, \$1.147 billion in 2019, and \$1.142 billion in 2020. Corteva’s research activities are likely divided between its crop protection business (based in Indianapolis) and seed business (based in Johnston, Iowa). From a revenue perspective, their 2020 split was approximately 45 percent in crop protection and 55 percent in seeds. If R&D expenditures matched this share, over \$500 million in additional R&D is performed in Indiana.<sup>8</sup>

<sup>7</sup> Data from Elanco Animal Health’s 10-K reporting forms.

<sup>8</sup> Data from Corteva’s 10-K reporting forms.



## 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 reflecting tangible innovation in both academic and industrial settings.

One indicator commonly used to assess a state's innovation activity 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 technology areas or market applications where Indiana has a competitive advantage in agbioscience innovation. Similarly, an examination of the agbioscience patent holdings assigned to Indiana companies can yield insights into the current industry environment and market areas where Indiana-based companies are advancing innovative products and technologies.

To evaluate this indicator within Indiana, TEconomy analyzed patent awards issued to Indiana inventors over the 2018–2021 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 876 total agbioscience patent awards generated in Indiana between 2018–2021. As with most states and the U.S. in general, the number of issued patents in 2020 and 2021 have been suppressed due to overall slowdowns in patent applications and approvals due to the COVID-19 pandemic's impact on business and government research.

Table 5 shows that Corteva (and its predecessor companies) is by far the largest generator of agbioscience patented innovations in Indiana—accounting for more than half of the state’s agbioscience-related patents. Monsanto (since acquired by Bayer) also holds multiple Indiana-inventor patent assignments. The generation of important agbioscience intellectual property (IP) is also evident in the 25 patents issued to Purdue.

**Table 5: Indiana Agbioscience Patents by Indiana Inventor (2018–2021)**

Assignee of Patent w/Indiana Inventor (2+ Patents)	Number of Patents
Corteva Agriscience (and Predecessors)	450
Bayer CropScience (Monsanto)	58
Purdue Research Foundation	25
Mid-West Metal Products Company, Inc.	24
CNH Industrial America LLC	17
Elanco U.S. Inc.	14
Hydro-Gear Limited Partnership	10
Rose Acre Farms Inc.	10
Adama Makhteshim Ltd. (Israel)	10
Fairlife LLC	9
Tate & Lyle Ingredients Americas LLC	8
Eco Sports Group Inc.	8
Reckitt Benckiser (Mead Johnson Nutrition)	7
Trade Secret Chocolates (aka SoChatti/True Essence Foods)	5
Limagrain Europe S.A (France)	4
E-Collar Technologies Inc.	4
Midwest Apple Improvement Association	4
Whirlpool Corporation	4
ABI Attachments Inc.	3
Biomeneral Systems LLC	3
CTB Inc.	3
Syngenta Participations AG (Switzerland)	3
Beck’s Superior Hybrids Inc.	2
<b>Total, Indiana Ag/bio-related Patents</b>	<b>876</b>

Source: TEconomy analysis of USPTO data as provided via Clarivate Analytics’ Derwent Innovation patent analysis database. Those firms in light green shaded rows are headquartered in Indiana.

Table 6 shows these 876 Indiana “inventor” agbioscience patents categorized into leading detailed technology classification areas. Novel Plant Types comprise the largest category of patents generated within the state, indicating a strong focus on innovative activity in this space, but also demonstrating the pandemic-related slowdown. Other leading areas include Genetic Engineering, Fertilizers and Agricultural Chemicals, and Animal Husbandry.

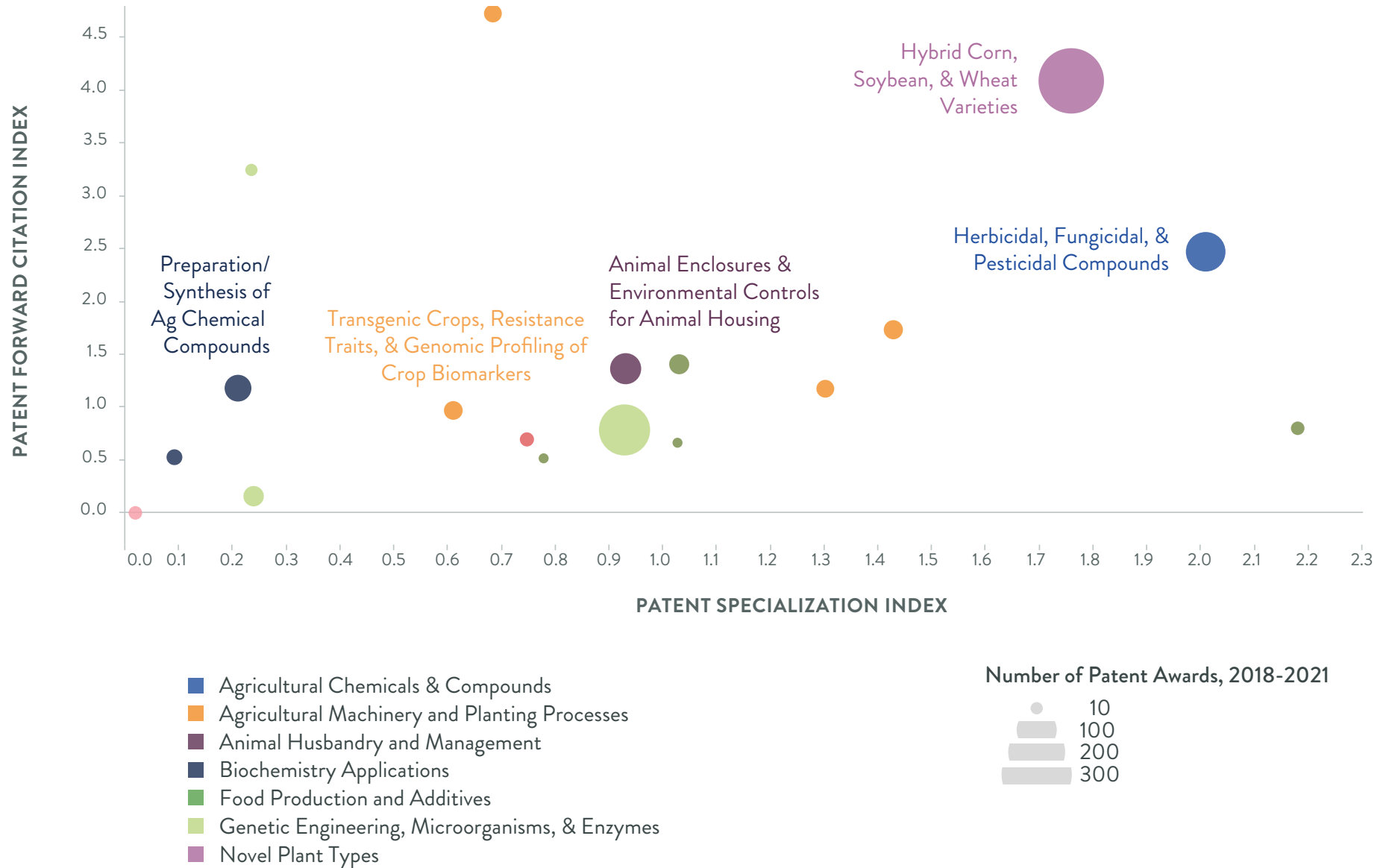
**Table 6: Indiana Agbioscience Patents (2018–2021)**

Ag/bio Patent Group (w/5+ Patents)	2018	2019	2020	2021	Total, 2018–2021
Novel Plant Types	92	74	58	33	257
Genetic Engineering, Microorganisms, or Enzymes	61	55	42	36	194
Fertilizers and Agricultural Chemicals	33	38	19	15	105
Animal Husbandry and Management	12	15	21	22	70
Food Production and Additives	11	17	12	23	63
Agricultural Machinery and Planting Processes	25	28			53
Veterinary Instruments, Tools, and Pharmaceuticals	7	3	1	2	13
Fermented Beverages	1	2	1	1	5
All Other Agbio and Related	34	16	36	30	116
<b>Total, Indiana Ag/bio-related Patents</b>	<b>276</b>	<b>248</b>	<b>190</b>	<b>162</b>	<b>876</b>

Source: TEconomy analysis of USPTO data as provided via Clarivate Analytics’ Derwent Innovation patent analysis database.

As an additional perspective in examining trends in patenting, Figure 10 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 the proportion of U.S. patenting in that area (>1 indicates more specialized relative to the U.S., <1 indicates less specialized). Similarly, a forward citation index shows the volume of forward citations for Indiana patents relative to the 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.

**Figure 10:** Indiana Agbioscience Patenting—Profile of Major Technology Areas (2018–2021)



Source: TEconomy analysis of USPTO data.

It is evident that Novel Plant Types, primarily hybrid corn/maize, soybean, and wheat varieties continue to be a standout area of high-volume, specialized patent activity for Indiana agbioscience while also generating over four times the expected forward citations level.

Additional areas of significant patenting volume include the following:

- Genotyping of crop biomarkers to ID advantageous traits and modify crop lines accordingly using genetic engineering (large, but neither specialized nor generating above average forward citations).
- A variety of herbicidal, fungicidal, and pesticidal compounds with specific synergistic or stability properties for use with crops (specialized and highly impactful in generating forward innovation).
- Animal enclosures and related environmental controls for animal housing (not specialized, but over 35 percent more citations than the national average).
- Key classes of biochemistry compounds primarily used in the preparation and synthesis of agricultural chemicals (not specialized but 17 percent more citations than the national average).

## Examining Patent Forward Citations

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.

## Graduate Output in Agbioscience and Associated Disciplines in Indiana

For an 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).

Table 7 shows that Indiana produced 1,222 graduates in 2021 with higher education degrees related to agbioscience and associated disciplines, up from 1,056 in comparable data for 2018. This graduate output included: 269 Associate’s degrees (22 percent); 614 Bachelor’s degrees (50 percent); 183 Master’s degrees (15 percent); 78 Doctoral (Ph.D.) degrees (6 percent), and 81 Doctor of Veterinary Medicine degrees (7 percent). Table 7 lists degrees ranked by the combined number of graduates in the discipline (including Associate’s through Doctoral degrees).

**Table 7: Graduate Output of Indiana Universities and Colleges in Fields Related to Agbiosciences (2020)**

Classification of Instructional Programming (CIP) Title	Associate's degree	Bachelor's degree	Master's degree	Doctor's degree - research/scholarship	Doctor's degree - professional practice	2020 Total
Agricultural Engineering	-	83	73	15	-	171
Animal Sciences, General	7	132	13	9	-	161
Agricultural Business and Management, General	23	128	-	-	-	151
Veterinary/Animal Health Tech/Veterinary Assistant	123	24	-	-	-	147
Agriculture, General	103	16	-	-	-	119
Veterinary Medicine	-	-	-	-	81	81
Agricultural Economics	-	30	39	8	-	77
Food Science	-	28	11	9	-	48
Nutrition Sciences	-	34	6	5	-	45
Agroecology and Sustainable Agriculture	-	35	-	-	-	35
Soil Science and Agronomy, General	-	2	11	12	-	25
Agricultural Mechanization, General	2	22	-	-	-	24
Horticultural Science	-	16	5	3	-	24
Botany/Plant Biology	-	12	6	6	-	24
Entomology	-	7	4	5	-	16
Agricultural Communication/Journalism	-	13	-	-	-	13
Farm/Farm and Ranch Management	-	12	-	-	-	12
Agricultural and Extension Education Services	-	-	5	6	-	11
Veterinary Sciences/ Clinical Sciences, General	-	-	10	-	-	10
Applied Horticulture/Horticulture Operations	9	-	-	-	-	9
Plant Genetics	-	6	-	-	-	6
Turf and Turfgrass Management	-	4	-	-	-	4
Agribusiness/Agricultural Business Operations	-	3	-	-	-	3
Agricultural Supplies Retailing and Wholesaling	-	3	-	-	-	3
Crop Production	-	3	-	-	-	3
Equestrian/Equine Studies	2	1	-	-	-	3
Total, All Agbioscience Degree Fields	269	614	183	78	81	1,225
<b>Share of Total Agbioscience Degrees</b>	<b>22%</b>	<b>50%</b>	<b>15%</b>	<b>6%</b>	<b>7%</b>	<b>100%</b>

Source: TEconomy analysis of NCES IPEDS data.

Note: Data represents degrees conferred and does not reflect individual student counts.

Table 8 compares changes across these agbioscience degree disciplines in terms of the number of degrees granted in 2018 and 2020—providing a percentage increase or decrease figure over the period for Bachelor’s degrees and higher and Doctoral degrees alone. **Overall, growth in key disciplines is evident in these data with a 6.6 percent increase in all Bachelor’s and higher degrees awarded and a 2.6 percent increase in awarded doctoral degrees.**

It is important to note the significant increase in Agricultural Engineering degrees in both actual degree awards (an increase of 54) leading to an increase of 46 percent. Of cautionary note is the fact that both food science and nutrition sciences declined by 18 and 17 degrees, respectively, or a significant 27 percent decrease for both.

**Table 8:** Comparison of 2012 and 2018 Graduate Output in Indiana Agbioscience Fields

Academic Degree Fields	IN Graduates (Bachelor’s & Higher)			IN Doctorate Degrees		
	2018	2020	% Change 2018-2020	2018	2020	% Change 2018-2020
Agricultural Engineering	117	171	46.2%	14	15	7.1%
Animal Sciences, General	158	154	-2.5%	9	9	0.0%
Agricultural Business and Management, General	120	128	6.7%	0	0	-
Veterinary/Animal Health Tech/Veterinary Assistant	14	24	71.4%	0	0	-
Agriculture, General	7	16	128.6%	0	0	-
Veterinary Medicine	74	81	9.5%	74	81	9.5%
Agricultural Economics	82	77	-6.1%	11	8	-27.3%
Food Science	66	48	-27.3%	11	9	-18.2%
Nutrition Sciences	62	45	-27.4%	13	5	-61.5%
Agroecology and Sustainable Agriculture	32	35	9.4%	0	0	-
Soil Science and Agronomy, General	17	25	47.1%	5	12	140.0%
Agricultural Mechanization, General	25	22	-12.0%	0	0	-
Horticultural Science	30	24	-20.0%	5	3	-40.0%
Botany/Plant Biology	30	24	-20.0%	4	6	50.0%
Entomology	16	16	0.0%	6	5	-16.7%
Agricultural Communication/Journalism	11	13	18.2%	0	0	-
Farm/Farm and Ranch Management	4	12	200.0%	0	0	-
Agricultural and Extension Education Services	9	11	22.2%	2	6	200.0%
Veterinary Sciences/ Clinical Sciences, General	10	10	0.0%	1	0	-100.0%
Applied Horticulture/ Horticulture Operations	0	0	-	0	0	-
Plant Genetics	6	6	0.0%	0	0	-
Turf and Turfgrass Management	4	4	0.0%	0	0	-
Agribusiness/Agricultural Business Operations	0	3	-	0	0	-
Agricultural/Farm Supplies Retailing and Wholesaling	0	3	-	0	0	-
Crop Production	0	3	-	0	0	-
Equestrian/Equine Studies	3	1	-66.7%	0	0	-
<b>Total, All Agbioscience Degree Fields</b>	<b>897</b>	<b>956</b>	<b>6.6%</b>	<b>155</b>	<b>159</b>	<b>2.6%</b>

Source: TEconomy analysis of NCES IPEDS data.

## 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 in Table 9 are three groupings of occupations related to agricultural science with data for Indiana. Among the Primary Agricultural Innovation occupations, it is evident that Indiana has a specialized concentration of agricultural technicians (LQ = 1.88 or 88 percent higher than the national average) and a concentration in animal scientists (16 percent higher) and agricultural engineers (7 percent higher). Within the Associated Occupations, Veterinary Assistants and Agricultural Equipment Operators show slight concentrations (4 percent and 3 percent above the national average, respectively). Across all 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 average levels.

**Table 9:** Indiana's Agbioscience Innovation-Related Occupational Employment (2021)

Occ. Code	Occupation	Indiana Employment 2021	Indiana LQ	Indiana Hourly Wage Mean	Indiana Annual Wage Mean	U.S. Hourly Wage Mean	U.S. Annual Wage Mean
<b>Primary Agricultural Innovation-Related Occupations</b>							
19-4012	Agricultural Technicians	664	1.88	\$23.01	\$47,857	\$21.51	\$44,731
19-1012	Food Scientists and Technologists	280	0.93	\$39.61	\$82,390	\$40.36	\$83,941
45-2011	Agricultural Inspectors	201	0.63	\$22.29	\$46,354	\$24.44	\$50,842
19-4013	Food Science Technicians	148	0.56	\$20.97	\$43,609	\$22.71	\$47,242
19-1011	Animal Scientists	81	1.16	\$38.63	\$80,352	\$38.47	\$80,026
17-2021	Agricultural Engineers	31	1.07	\$46.54	\$96,803	\$41.99	\$87,339
	Primary Occupations Subtotal	1,404	1.05				
<b>Secondary Agricultural Innovation-Related Occupations</b>							
29-1131	Veterinarians	1,606	0.97	\$47.70	\$99,216	\$52.84	\$109,907
19-4021	Biological Technicians	741	0.45	\$20.13	\$41,870	\$24.89	\$51,771
19-1022	Microbiologists	300	0.69	\$28.99	\$60,299	\$42.22	\$87,818
19-1031	Conservation Scientists	290	0.56	\$30.62	\$63,684	\$32.38	\$67,353
19-1021	Biochemists and Biophysicists	241	0.31	\$47.50	\$98,800	\$54.55	\$113,464
19-1023	Zoologists and Wildlife Biologists	168	0.46	\$26.56	\$55,245	\$33.80	\$70,304
	Secondary Occupations Subtotal	3,347	0.62				
<b>Other Associated Occupations</b>							
39-2021	Animal Caretakers	4,956	0.98	\$12.97	\$26,978	\$14.19	\$29,515
29-2056	Veterinary Technologists and Technicians	2,238	0.88	\$16.94	\$35,235	\$18.39	\$38,251
31-9096	Veterinary Assistants and Laboratory Animal Caretakers	2,193	1.04	\$13.87	\$28,850	\$15.28	\$31,782
45-2091	Agricultural Equipment Operators	1,410	1.03	\$16.20	\$33,686	\$15.80	\$32,871
45-2099	Agricultural Workers, All Other	992	0.79	\$15.29	\$31,809	\$16.06	\$33,403
19-1029	Biological Scientists, All Other	402	0.39	\$32.86	\$68,349	\$43.27	\$90,002
	Other Occupations Subtotal	12,192	0.91				

Source: TEconomy analysis of BLS Occupational Employment Statistics Program data as available from the Lightcast Developer database, Datarun 2022.4.



## 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, 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—most recently Dr. Clint Chapple, distinguished professor of biochemistry, was elected in May 2022—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 the performance of research with \$86.5 million in fiscal year 2022 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 10,500 acres of Purdue University agricultural land, including eight Purdue Agricultural Centers across Indiana, to facilitate research and field trial activity, and Purdue Extension reaching all 92 Indiana counties in the 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. 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:

- **Plant Sciences 2.0** was launched in April 2021 as part of Purdue's Next Moves strategic initiatives. Building on the university's original investment in plant sciences, the new investment broadens the focus to include digital forestry and food systems. In February 2022, the Purdue Board of Trustees approved a \$20M allocation toward a phenotyping greenhouse facility that will expand opportunities for non-invasive sensor-based phenotyping and add nearly 5,000 square feet of greenhouse research space. Construction is scheduled to start in November 2023 with occupancy anticipated to begin by August 2024.
- **The Plant Sciences Institute** is the university's investment in plant science research at the launch of Purdue Moves in 2013 and 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. Since the institution's inception, the College of Agriculture has generated over \$200 million in gifts and external grants.

- The **Ag-Celerator** is a \$2 million plant sciences innovation fund launched to provide critical start-up support for Purdue innovators looking to commercialize patented IP or Purdue plant science technologies. As of 2022, Ag-Celerator has funded 18 start-ups and invested \$1.4M.
  - 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 seven departments. The center provides a dynamic training environment for graduate students and is doing cutting-edge research in basic plant biology that paves the way to improve plant growth and sustainability in a changing climate.
  - 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. Partnering with the University of Pennsylvania, Purdue is home to the Engineering Research Center on IoT for Agriculture.
  - Both controlled environment and field phenotyping facilities are online and being used by hundreds of researchers.
- 
- **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 coupled with a \$6M investment by the University, 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 1,300 unmanned aerial vehicle (UAV) flights; hosted 7,219 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 the Spring of 2018 to run experiments under highly uniform growth conditions that cannot be easily controlled in the field. The chambers control the intensity and pattern of light exposure, fertilization, watering, and CO<sub>2</sub> levels so that a full range of environmental conditions can be assessed. This is coupled with a full range of sensing capabilities, including hyperspectral imagery (HSI), red-green-blue (RGB), shortwave infrared (SWIR), and computed tomography (CT) to enable researchers to study below- and above-ground plant traits from seedlings to full-height corn. The facility also includes an X-ray CT scanner to non-destructively image roots in 3-D, which is a unique capability across the country. Since its opening, the facility has run 177 experiments; hosted 3,029 visitors; and studied 22 different plant species (including soybean, corn, wheat, sorghum, switchgrass, tomato, cacao, cotton, hemp, rice, basil, kale, and garlic).
  - **Purdue established the North American Plant Phenotyping Network (NAPPN) and hosted its inaugural event. In 2024, the event will return to Purdue University.**

- Purdue broadened student reach and training through the following:
  - The **Summer College of Agriculture Research Fellowship (SCARF)** and Ag Science Research Institute expose undergraduate and high school students to plant sciences and molecular agriculture research. These programs attract students into science, technology, engineering, and mathematics (STEM); promote undergraduate research; and stimulate student and faculty collaboration. Since its inception, 81 undergraduates and 91 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 was also 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, 19 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 has the largest collection of weeds in the country, and 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** facilitates cross-disciplinary and cross-college research, teaching, and outreach focusing on addressing contentious social issues in animal behavior and welfare 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 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 on 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 the 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:

- As part of Purdue Next Moves Plant Sciences 2.0, the **Center for Food Demand Analysis and Sustainability (CFDAS)** tracks consumer insights and the economics of the food system to produce timely reports on trends and emerging topics. The data created and communicated helps producers, policymakers, and agribusinesses make decisions that will improve the food system as well as guide research on nutrition and plant innovations.
- **Digital Innovation in Agri-food Systems Laboratory (DIAL Ventures)** is part of the Purdue Applied Research Institute (PARI) and works on big problems facing agriculture through new digital innovations. Working with venture partners, DIAL work to bring innovative new startups to market.
- **Food Entrepreneurship and Manufacturing Institute (FEMI)** is a new effort to fuel economic growth in the region by enabling food and beverage companies to ideate, develop, and commercialize novel, improved, and sustainable products. It is also hiring undergraduate and graduate students to work in teams to lead projects. In its first six months, FEMI had 20 active projects and hosted more than 100 exploratory calls.
- **Purdue Center for Commercial Agriculture** offers programs, events, and resources specifically designed to help farmers evaluate their options and be more strategic in their farm business operations. The center partners with the CME Group on the monthly Ag Economy Barometer, which is a nationwide measure of the health of the U.S. agricultural economy.
- **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 policymakers 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 an effort to meet the Global Sustainable Development Goals of a changing planet with limited land and water resources. GLASS provides a network that highlights tradeoffs and synergies associated with policies tackling sustainable development goals. They produce policy briefs and other actionable recommendations for achieving 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 ten 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 six 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:

- The **Center for Digital Forestry** is leveraging digital technology and multidisciplinary expertise to measure, monitor, and manage urban and rural forests to maximize social, economic, and ecological benefits. As part of Plant Sciences 2.0, investments in remote sensing tools and technologies, data management infrastructure, and personnel have accelerated the college's leadership in this space. Purdue Agriculture researchers received \$45M in new federal funding for digital forestry research over the last year.
- **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 an **NSF-funded Engineering Research Center for the Internet of Things for Precision Agriculture (IoT4Ag)** where more than two dozen researchers from four institutions 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 several centers and initiatives across Purdue's campus, including the Center for Global Food Security, Open Agriculture Technology and Systems (OATS) 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 the 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, two air-conditioned growth rooms; 17 growth chambers; five walk-in coolers; a tissue culture laboratory; three 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 >1,400-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 the microscopic and submicroscopic structures 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 science 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 District Centers and Institutes**, 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 six 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, Bindley BioScience Center, Birck Nanotechnology Center, Institute for a Sustainable Future, 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. Bayer and Beck’s Hybrids have space in Convergence.
- **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.
- 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. In 2022, Inari announced an expansion of its operations within Purdue Research Park with a new 42,000 square-foot greenhouse and an additional 140 jobs.
- 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 now doing business as anuTM, 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. The start-up from Purdue Foundry’s Startup Class of 2017 recently received a Phase II National Science Foundation Small Business Innovation Research grant and matching funding from Elevate Ventures.

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 six locations in Indiana and 260 companies with more than 4,500 jobs. An independent study reports that the park network provides an annual economic impact of \$1.3 billion to the State of Indiana.

# CHAPTER IV. AGBIOSCIENCE INNOVATION IN INDIANA

## Innovative Agbioscience Drivers in Indiana

As Chapter II shows, Indiana has significant strengths in production agriculture, inputs to production (including seeds, agricultural chemicals, and animal medicines and vaccines), and food and beverage manufacturing. Chapter III demonstrates that Indiana also continues to benefit from an agbioscience research base that is broad in terms of its areas of strength but driven primarily by the efforts of a few corporate entities and Purdue University’s College of Agriculture. In general, the strengths identified in the innovation analysis, when combined with the review of Indiana’s agbioscience business profile, continue to support the existing emphasis of AgriNovus Indiana that concentrates work across four principal platforms (Figure 11).

**Figure 11:** Indiana Agbioscience Innovation Platforms

INDIANA AGBIOSCIENCE INNOVATION PLATFORMS			
<p><b>Value-Added Food and Nutrition</b></p> <p>Establishments = 102                      Employment = 17,927                      Publications = 599                      Patents = 78</p>	<p><b>Plant Science and Crop Protection</b></p> <p>Establishments = 42                      Employment = 3,470                      Publications = 1,443                      Patents = 591</p>	<p><b>Agricultural Equipment, Technologies, and Systems</b></p> <p>Establishments = 53                      Employment = 2,663                      Publications = 165                      Patents = 177</p>	<p><b>Animal Health and Nutrition</b></p> <p>Establishments = 23                      Employment = 1,849                      Publications = 843                      Patents = 22</p>

Source: TEconomy Partners, LLC.

Each platform is a base for significant economic and innovation activity in Indiana. The platforms capture a significant base of industry establishments, ranging from a high of 102 establishments in the Value-Added Food and Nutrition platform to a low of 23 in the Animal Health and Nutrition platform. Combined, there are 25,909 personnel employed in the innovative companies identified for each of these platforms. Innovation can take many forms in both product development and manufacturing as well as processing improvements and can be partially seen in the summary publication and patent statistics for each platform in Figure 11.

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



## Value-Added Food and Nutrition

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### What Does This Sector Do?

Businesses and innovators in this platform 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 major industry in Indiana and nationally. While many foods (e.g., fruits and vegetables) may be shipped to market with limited additional processing, a large volume of farmgate commodities will be subject to further processing before they are ready for market. These processes all provide opportunities for innovation and productivity enhancements that employ Indiana workers. In several instances, these processes are reflected in specific occupations within the food processing industry (key platform occupation) and include areas such as:<sup>9</sup>

- Baking – a key platform occupation
- Batch making – a key platform occupation
- Blending, mixing, and emulsifying
- Canning and freezing
- Chopping and slicing
- Cooking, boiling, frying, grilling, and steaming
- Curing, pickling, marinating, and smoking
- Cutting and trimming – a key platform occupation
- Fermenting
- Filtering and clarifying – a key platform occupation
- Freeze-drying
- Grinding and milling
- Packing and Packaging – a key platform occupation.

In addition to direct food and beverage products, agricultural output can also be feedstocks that are further processed to extract or enhance specific value-added nutrients, vitamins, compounds, 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 unique medical or health benefits. Nutraceuticals, in particular, form a unique bridge between food and medicine and include products ranging from vitamins, minerals, botanicals and their extracts, amino acids, and other concentrates and extracts, all falling under the auspices of the U.S. Food and Drug Administration.

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<sup>9</sup> Those processes identified as a key platform occupation have corresponding occupational classes that account for 500 or more Indiana workers in 2021 according to Lightcast data.

## Why Is This an Opportunity for Indiana?

*Currently, there are 102 establishments identified in Indiana as engaged in value-added food and nutrition research and production with a significant employment base of 17,927. Example firms include ADM, AmeriQual, Artemis International, Cargill, Clabber Girl, Clif Bar, Farbest Foods, Frito-Lay, Ingredion, Kerry Ingredients, Maple Leaf Farms, Mead Johnson, Park 100 Foods, Red Gold, Tyson, and Weaver Popcorn.*

According to IBISWorld data, the overall U.S. market for food and beverage products is expected to grow by 2.7 percent (or a CAGR of 0.54 percent) from 2023 to 2028. U.S. market forecasts for key segments in which Indiana has substantial employment and output include:

- Sales from the U.S. dairy processing industry are expected to remain flat increasing by only 1.3 percent from 2023 to 2028, reaching nearly \$166 billion by 2028.<sup>10</sup>
- Sales from the U.S. meat, beef, and poultry processing industry are expected to remain flat increasing by 1.5 percent from 2023 to 2028, reaching over \$300 billion by 2028.<sup>11</sup>
- Sales from the U.S. retail and commercial bakery industry are expected to grow slightly increasing by 1.6 percent from 2023 to 2028, reaching nearly \$54 billion by 2028.<sup>12</sup>
- Sales from the U.S. snack food industry are expected to grow significantly, increasing by 9.7 percent from 2023 to 2028, reaching over \$53 billion by 2028.<sup>13</sup>

The unique and niche opportunities for industry growth through functional foods and nutraceuticals are one area where Indiana should have some competitive advantages given the combined strengths of the biopharmaceutical industry and the agbioscience industry in the state.

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:<sup>14</sup>

- The global nutraceutical market should grow from \$289.8 billion in 2021 to \$438.9 billion by 2026, at a compound annual growth rate (CAGR) of 8.7 percent for the period of 2021-2026.
- Functional beverages as a product of the nutraceutical market should grow from \$104.3 billion in 2021 to \$162.4 billion by 2026, at a CAGR of 9.3 percent for the period of 2021-2026.
- Functional food as a product of the nutraceutical market should grow from \$94.2 billion in 2021 to \$144.9 billion by 2026, at a CAGR of 9.0 percent for the period of 2021-2026.
- Dietary supplements as a product of the nutraceutical market should grow from \$91.3 billion in 2021 to \$131.7 billion in 2026, at a CAGR of 7.6 percent for the period.

These various forms of nutraceuticals align with many of Indiana's key food subsectors including bakery, snacks, and even meat. All these form factors are expected to grow by a CAGR of 8 percent or more from 2021-2026.

Many of Indiana's food processing firms are an important part of the national landscape of firms feeding Hoosiers and other Americans. 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

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<sup>10</sup> IBISWorld, NAICS 31151 Dairy Product Production in the US, January 2023.

<sup>11</sup> IBISWorld, NAICS 31161 Meat, Beef & Poultry Processing in the US, January 2023.

<sup>12</sup> IBISWorld, NAICS 31181 Bread Production in the US, January 2023.

<sup>13</sup> IBISWorld, NAICS 31191 Snack Food Production in the US, January 2023.

<sup>14</sup> BCC Research, Nutraceuticals: Global Markets to 2026, December 2021.

increasing the value of Indiana’s commodities and specialty agricultural products and expanding the market opportunities for the state’s food processors.

### Recent Innovation Performance: Value-Added Food and Nutrition

Research within the Value-Added Food and Nutrition platform is driven by Purdue University, accounting for 481 out of the total 599 publications (Table 10). Key areas of research include a broad range of food chemistry-related research, dairy science (including the relationship between feed, animal health, and output quality), food safety, and nutrition.

From a patent perspective, the innovation captured within this platform is led by work in milk/dairy processing and products (Fairlife/Fair Oak Farms), infant nutrition from Reckitt Benckiser (formerly Mead Johnson), and the development of starch-related inputs from Primary Products Ingredients Americas (formerly Tate & Lyle).

**Table 10:** Indiana Value-Added Food and Nutrition Platform - Research and Innovation Output, 2018–2021

<b>Research Publications</b>	<p><b>Total Publications:</b> 599</p> <p><b>Key Disciplines:</b> Food Science and Technology, Plant Sciences, Agriculture &amp; Dairy/Animal Science, Horticulture, Multidisciplinary Agriculture, and Chemical Engineering.</p> <p><b>Key Corporate Research:</b> Corteva—19 publications in this platform (food safety related to chemicals) Eli Lilly &amp; Co.—9 publications in this platform Nestle (Switzerland)—6 publications in this platform Reckitt Benckiser/Mead Johnson—5 publications in this platform</p>
<b>Patents</b>	<p><b>Patents Assigned to Indiana Companies/Individuals:</b> 34</p> <p><b>Patents Assigned to Indiana Inventors:</b> 78</p> <p><b>Key Corporate Assignees:</b> Fairlife LLC—9 patents Primary Products Ingredients Americas (formerly Tate &amp; Lyle)—7 patents Reckitt Benckiser (fka Mead Johnson Nutrition Company) —7 patents Provisur Technologies, Inc.—5 patents Trade Secret Chocolates (SoChatti/ True Essence Foods)—5 patents</p>

Sources: TEconomy analysis using data from Clarivate Analytics’ Web of Science database and Clarivate Analytics’ Derwent Innovation patent analysis database.

Federally funded research is driven by Purdue University with over \$3.4 million in project-specific competitive (non-capacity grant) funding (Table 11). From an investment capital perspective over the 2018–2021 period, Market Wagon, an operator of an online farmers marketplace, received \$11.35 million, the Long Drink Company, a distillery products producer, received \$11.25 million, and True Essence Foods (aka SoChatti), a producer of artisanal dairy-free chocolate, received \$10.13 million.

**Table 11: Indiana Value-Added Food and Nutrition Platform - Innovation Resources and Capital, 2018–2021**

<p><b>USDA-Competitively Funded Research (non-SBIR)</b></p>	<p><b>Purdue University</b>—12 Awards—\$3,407,870  <b>State Total</b>—13 Awards—\$3,874,243</p>
<p><b>SBIR Awards</b></p>	<p><b>2 Awards</b>  <b>JUA Technologies International LLC</b>                  2019 Phase I—\$100,000  <i>Smart Multipurpose Solar Dehydration Device for Value Addition to Specialty Crops</i>  <b>NutraMaize</b>                  2019 Phase II—\$1,260,400  <i>Developing High Carotenoid Orange Corn for Large-scale Commercial Adoption</i></p>
<p><b>Angel &amp; Venture Capital</b></p>	<p><b>Summary</b>                  Companies—20                  Deals—38                  Investment—\$51.56 million  <b>By Deal Type</b>                  Pre-Seed—1 Deal—\$2,000                  Angel—11 Deals—\$3.19 million                  Seed—7 Deals—\$2.66 million                  Early Stage—10 Deals—\$22.19 million                  Later Stage—8 Deals—\$23.45 million</p>

Sources: TEconomy analysis using data from the U.S. Department of Agriculture and SBIR.gov, and Pitchbook venture capital database.

## Companies that are Actively Involved in 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 food service 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.
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 allows 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.
Anu (fka Heliponix LLC)	Anu, 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.
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.
Atarraya Inc.	Atarraya Inc., the creator of Shrimpbox, is the developer of the first sustainable 'plug-and-play' shrimp farming technology that transforms aquaculture production.
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 a 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.

Company Name	Innovation Area Descriptions
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.
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.
Clif Bar & Company	Clif Bar & Company, a maker of organic, plant-based energy food and nutrition bars operates one of its manufacturing facilities in Indianapolis.
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 food service 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.
Crystal Lake, LLC	Crystal Lake, LLC produces egg products for the food service and food manufacturing industries, including frozen, liquid, and hard-cooked eggs, as well as offering dried products and specialty pre-cooked items.
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.
Egg Innovations	Egg Innovations is a leading producer of cage-free and organic eggs. The cooperative supplies Omega 3 and vegetarian eggs (produced by hens with a vegetarian diet), as well as cage-free and organic products through regenerative farming practices.
Epogee	Epogee is an innovative food ingredients company, having developed a patented fat replacement technology, that partners with food manufacturers 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 Food Service	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.
Gavilon (Viterra)	Gavilon - A Viterra Company - specializes in the origination, storage, and distribution of grains and oilseeds as well as feed and food ingredients to domestic and global markets.
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 percent 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.
Greenleaf Foods	Greenleaf Foods, an independent subsidiary of Maple Leaf Foods, produces plant-based foods such as sausages, burgers, hot dogs, and raw meat alternatives.
Hard Truth Distilling Company	Hard Truth Distilling Co. operates a state-of-the-art distillery producing a variety of premium spirits.
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.
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 pork-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.
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 provides packaging and testing services.
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 ingredient, 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 food service markets throughout the world with innovative, value-added foods.
Market Wagon	Market Wagon is an online ordering and delivery service for ordering produce, meat, dairy, and prepared foods from local farmers and artisan food producers founded in Indianapolis in 2016.
Mariah Foods Corp.	Mariah Foods Corp. (trade name Peer Foods) is a meat-packing plant.
Middlebury Cheese Co. LLC	Middlebury Cheese Company LLC is a cheese manufacturer.
Miller Poultry	Miller Poultry is a vertically integrated poultry company.

Company Name	Innovation Area Descriptions
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, ice cream, and other frozen foods.
Newfangled Confections	Newfangled Confections makes hand-crafted chocolates.
Ninth Avenue Foods	Ninth Avenue Foods specializes in producing extended shelf-life dairy and dairy alternative products. A combination of high-temperature and an ultra-clean filling environment enables Ninth Avenue Foods to package dairy and nondairy products with an extended shelf-life while maintaining the nutritional benefits of the product.
NouvEau Inc.	NouvEau Inc. is a patent and IP holding company for the license of the manufacturing 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 food service and consumers. The variety was developed at Purdue as part of an ongoing humanitarian effort to relieve global vitamin A deficiencies.
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 provides technical services for product formulation and processing design.
Primary Products Ingredients Americas - Lafayette North Plant	Primary Products Ingredients Americas (formerly Tate & Lyle) is a multinational starch manufacturer and wet corn mill that also produces animal feed and ingredients for the food and beverage industries.
Pure Green Farms	Pure Green Farms is a greenhouse grower of leafy greens year-round using hydroponic and environmentally friendly practices to produce high quality.
Quaff ON! Brewing Company	Quaff ON! Brewing Company brews and distributes hand-crafted beers.
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.
Reckitt Benckiser Group PLC (fka Mead Johnson Nutrition Company)	Reckitt Benckiser Group PLC (fka 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.
Red Gold	Red Gold produces a variety of canned tomato products for the food service industry.
Richmond Baking Co.	Richmond Baking offers breading 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.



Company Name	Innovation Area Descriptions
SmithFoods Richmond Inc.	SmithFoods Richmond Inc. is a national food manufacturer and distributor of dairy and non-dairy fluid products. The company serves national, regional, and local customers through a significant footprint covering the Midwest and Eastern United States.
Switchyard Brewery	Switchyard Brewery is a craft brewery in Bloomington that includes a co-working space that encourages entrepreneurship.
True Essence Foods (aka SoChatti and Trade Secret Chocolates LLC)	True Essence Foods began as an artisanal chocolate maker of the SoChatti chocolate brand, but has transitioned into an emerging food tech innovator creating a more sustainable and flavorful global food chain through its food waste and shelf stability products and technologies.
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 Laboratories Inc. manufactures and sells commercial cutting equipment to food-processing and allied industries.
Utz Quality Foods (fka Inventure Foods)	Utz Quality Foods (fka Inventure Foods) is a manufacturer producing a range of savory snack foods as well as smoothies, frozen berries, and frozen coffee.
Weaver Popcorn Company	Weaver Popcorn is a producer of microwave and concession popcorn.
West Fork Whiskey Company	West Fork Whiskey Company is a distillery.

## CASE STUDIES: TRUE ESSENCE FOODS



True Essence Foods is an Indianapolis-based food tech company that aligns with partners at every stage of the supply chain to create solutions to food waste and availability challenges by improving shelf stability while maintaining and preserving flavor via its portfolio of first-to-market products and technologies.

What began as quest by founder Matt Rubin to create a better-tasting, artisanal, vegan chocolate (SoChatti) has transformed into a food processing approach that emphasizes an all-encompassing sustainability solution. Rubin has been quoted as saying, “We’re building a company that is really focused on redefining flavor for the global good by enabling industrial food processing to have sustainable solutions in their facilities, [and to take] processed food to a new level.” The company’s goal is to not only improve taste and longevity of fresh products, such as fruits, vegetables and juices, but to prompt change in the industrial food complex by adopting sustainable manufacturing processes and reducing waste.

True Essence’s business is based on two distinct food processing platforms, both patented processes. The first is known as Flavor Symmetry, a form of dehydration that does not use heat, but instead uses a revolutionary process whereby only the moisture is removed from the product, essentially leaving the product raw, and with the majority of aroma and flavor retained. Using this technique, the shelf life of the food is increased along with a reduction in weight and volume, which allow for reduced transportation and storage costs. Leveraging the technology responsible for its groundbreaking flavor preservation and shelf stability achievements in the chocolate category, True Essence is testing and executing with more than 15 industrial company partners across a variety of food and beverage categories, including juices and concentrates, fruits and vegetables, and herbs, spices and cannabinoids.

The second, newer process is known as Flavor Balancing, and uses a rapid pressurization process to remove fermentation byproducts, dissolved oxygen, and microbubbles that negatively affect the flavor experience of beer, wines, spirits, and kombucha.

The company had its first major investment in 2020 when it closed on a \$2.2 million Series A funding round. A year later, the company secured \$5.25 million in a Series A2 funding round with participation from Elevate Ventures among other private investors. The funding will help True Essence acquire necessary equipment to expand R&D efforts, scale sales distribution of existing first-to-market products including SoChatti chocolate and True Essence Fruit Nectars, and dedicate the necessary resources to securing and supporting platform partners launching True Essence solutions and products into the market. The company has also finalized its first industrial licensing agreement with organic juice bar and restaurant, Greenleaf Foods Inc. The company has doubled its footprint on the near east side of downtown Indianapolis as it explores new technology and runs tests on various food products.

## CASE STUDIES: ATARRAYA INC.



Atarraya Inc is the creator of Shrimpbox, a sustainable “plug-and-play” shrimp farming technology. Housed in traditional cargo containers, Atarraya’s AI-powered Shrimpbox shrimp farming technology provides a sustainable, globally scalable protein source that creates new opportunities for farmers, even in landlocked, urban locations. Atarraya’s Shrimpbox uses biotechnology, artificial intelligence, and automation, and allows shrimp to be farmed locally, anywhere in the world. Unlike traditional shrimp farming, Shrimpbox operates with zero water pollution, eliminates the need for antibiotics or chemicals and produces fresh, healthy shrimp anywhere. The company focuses on the optimization of every aspect of shrimp farming, from R&D to breeding to production to marketing to even software and hardware development.

The technology includes biofloc technology, which creates an ideal environment for the shrimp. Then there is the software aspect that enables remote operation management of the production and workflow mapped out with data so that it is easier to train and perform the farming tasks. Finally, artificial intelligence-powered automation and engineering components are designed to remote-monitor the water quality, regulate temperature and oxygenation, and feed the shrimp. Atarraya’s proprietary biotechnology, Shrimpbox, is designed to decrease the environmental impact and cost of shrimp farming while allowing for production of fresh, sustainable, and local shrimp everywhere in the world. A Shrimpbox farm system enables farmers to become vertical aquaculture farming operations.

While the company is headquartered in Mexico, it announced in 2022 that it plans to invest \$4.8 million in a new facility in Indianapolis that will serve as the first sustainable shrimp production operation in the nation. Based on the company’s job creation plans, the Indiana Economic Development Corporation committed an investment of up to \$1 million in Atarraya through incentive-based tax credits and up to \$50,000 in training grants.

In making the site announcement, Daniel Russek, CEO and founder of Atarraya stated, “We are excited to start in the U.S. agriculture capital of Indiana, which we believe will rapidly become the nation’s agtech capital.”

Only two months after making the Indianapolis location announcement, Atarraya and BiomEdit, a microbiome innovator focused on animal health, announced a research collaboration to investigate microbial changes to improve the cost-effectiveness, sustainability and production output associated with shrimp farming. Elanco and Ginkgo Bioworks launched BiomEdit earlier in 2022. BiomEdit’s CEO is the former Elanco Executive Vice President of Innovation, Regulatory and Business Development, Aaron Schacht. Elanco contributes intellectual property and a pipeline of ongoing programs to BiomEdit, which is staffed with members of the former Elanco microbiome R&D team. The team brings the expertise and experience needed to build on the foundation of microbiome work started at Elanco. By leveraging foundational programs from Elanco, intellectual property from both Elanco and Ginkgo, and an experienced team, BiomEdit is well positioned as a stand-alone company to develop and launch innovative products to address unmet needs in animal health, such as its collaboration with Atarraya.

## Plant Science and Crop Protection

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### What Does This Sector Do?

Firms and organizations working within this platform are engaged in crop improvement and crop protection via the application of agronomy, 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, plant growth stimulants, herbicides, and pesticides), and more recently their biologically based equivalents.

The key innovation goal within this platform is to enhance the productivity of production agriculture by creating crops with higher yields, resistance to abiotic stress (such as drought, heat, or frost tolerance), and resistance to biotic stress and losses caused by pests and plant diseases. Enhancements may be generated through traditional breeding/hybridization techniques as well as advanced genomics technologies. Innovators in this space may also work to introduce crop varieties with enhanced functional characteristics (nutrition content, digestibility, color, flavor, shape, downstream processability characteristics, etc.). Chemistry is also an important area of activity in this sector, with companies engaged in developing targeted crop protection chemicals, fertilizers, soil inoculants, and other chemical and biologic inputs to production.

### Why Is This an Opportunity for Indiana?

*Currently, 42 establishments with 3,470 employees are classified into this innovation platform. Example firms include Ag Alumni Seed, Agdia, AgReliant Genetics, Beck's Hybrids, Benson Hill, Corteva, Lord's Seeds, SePRO Corporation, Remington Seeds, and Tom Farms.*

The Business Research Company (TBRC) calculated the global market for crop agriculture at \$4.76 trillion for 2021.<sup>15</sup> Crop production experienced a strong CAGR of 4.91 percent from 2016–2021 and is expected to reach a forecast CAGR of 11.56 percent from 2021–2026. Much of this growth is expected to come from the Asia Pacific region, which already accounts for over half (54 percent) of the total global agricultural market.

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 both fertilizer and crop protection products) is projected by TBRC to grow steadily from an estimated \$241.9 billion in 2022 to \$334.1 billion by 2027.<sup>16</sup> Of this, pesticides and other non-fertilizer agricultural chemicals are expected to account for more than \$89.3 billion in 2022 and potentially reach over \$128.6 billion by 2027.

### Recent Innovation Performance: Plant Science and Crop Protection

From a research and IP perspective, Indiana's powerful combination of university research and corporate research is highlighted within the Plant Science and Crop Protection platform (Table 12). From 2018–2021, Purdue University alone accounted for 1,047 of the platform-related research publications. These publications covered the breadth of the platform including plant sciences, agronomy, and entomology. From a corporate perspective, Corteva (and its predecessor companies' Indiana-based employees) accounted for 129 research publications over this four-year period focused primarily on the same three publication disciplines.

While the changing corporate structure of what is now Corteva may blur the line of what constitutes an "Indiana" patent, the output cannot be denied. The patents assigned to Corteva (and its predecessor organizations) with at least one Indiana inventor

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<sup>15</sup> TBRC. *Agriculture Market Global Briefing 2022*. May 2022.

<sup>16</sup> TBRC. *Agrochemicals Global Market Report*. January 2023. TEconomy calculations

involved show substantial activity in new plant/hybrid development (183 patents), genetic engineering (120 patents), and the development of pesticides, herbicides, and plant growth regulators (74 patents).

**Table 12:** Indiana Plant Science and Crop Protection Platform - Research and Innovation Output, 2018–2021

<b>Research Publications</b>	<p><b>Total Publications:</b> 1,443</p> <p><b>Key Disciplines:</b> Plant Sciences, Agronomy, Horticulture, Entomology, Forestry, Soil Science, Biochemistry/Molecular Biology.</p> <p><b>Key Corporate Research:</b> Corteva (including Dow AgroSciences and DuPont Pioneer)—129 publications in this Platform. Agdia—3 publications in this Platform.</p>
<b>Patents</b>	<p><b>Patents Assigned to Indiana Companies:</b> 349 (not including patents currently assigned to Dow Agrisciences in Iowa)</p> <p><b>Patents Assigned to Indiana Inventors:</b> 591</p> <p><b>Key Corporate Assignees:</b> Corteva (including Dow AgroSciences and DuPont Pioneer)—478 in this Platform; 798 Total</p>

Sources: TEconomy analysis using data from Clarivate Analytics' Web of Science database and Clarivate Analytics' Derwent Innovation patent analysis database.

Not surprisingly, given the strength of its College of Agriculture, Purdue University received 32 competitively awarded research grants totaling more than \$24 million over the 2018–2021 period (Table 13). This research included investigations into pest management, bees and other pollinators, and agronomy. Indiana University also provides its unique research capacities to this platform with research into plant biology and carbon, nitrogen, and water uptake and cycling.

From an SBIR perspective, Agdia's technology efforts are geared toward rapid virus identification (also cross-cutting with the Agricultural Equipment, Technologies, and Systems platform), while Biomineral Systems' efforts are focused on the developing area of biofertilizers, using living microbes that enhance plant nutrition.

**Table 13:** Indiana Plant Science and Crop Protection Platform - Innovation Resources and Capital, 2018–2021

<b>USDA-Funded Research (non-SBIR)</b>	<p><b>Purdue University</b>—32 Awards—\$24,270,937</p> <p><b>Indiana University</b>—8 Awards—\$1,869,949</p> <p><b>State Total</b>—40 Awards—\$26,140,886</p>
<b>SBIR Awards</b>	<p><b>2 Awards</b></p> <p><b>Agdia Inc.</b> 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></p> <p><b>Biomineral Systems LLC</b> 2018 Phase I—\$100,000 <i>Phosphorus Biofertilizer for Sustainable Crop Production</i></p>
<b>Angel &amp; Venture Capital</b>	<p><b>None</b> – However some firms captured within the Agricultural Equipment, Technologies, and Systems platform are related to plant science/plant-specific efforts.</p>

Sources: TEconomy analysis using data from the U.S. Department of Agriculture and SBIR.gov, and Pitchbook venture capital database.

## Companies that are Actively Involved in 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.
Ag Alumni Seed	Ag Alumni Seed is a supplier of high-performance popcorn, oat, and soft red winter wheat hybrid seed stock.
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.
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.
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.
Benson Hill	Benson Hill, a food tech company based in St. Louis, expanded its ingredients infrastructure by purchasing a former Rose Acre Farms soybean crushing facility.
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.
Ceres Solutions	Ceres Solutions is a 100 percent farmer-owned local cooperative based in Crawfordsville, Indiana providing energy, agronomy, seed, and animal nutrition products and services, as well as information and technology solutions to farmer members.
Co-Alliance	Co-Alliance is the result of the merger of five cooperatives and is now one of the largest agribusiness and energy marketing and supply cooperatives in the Midwest.
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.
DPH Biologicals	DPH Biologicals is a biologicals provider serving the row and specialty crop, turf, and ornamental markets.
EnviroKure	EnviroKure manufactures liquid organic fertilizer that is intended to provide a sustainable alternative to improve soil quality while reducing the burden of excess poultry manure. The company's fertilizer protects plants from biotic and abiotic threats, produces enzymes vital to nutrient cycling, and eliminates pathogens and antibiotic residues, enabling farmers to have pathogen-free biostimulants for agriculture, horticulture, and indoor crop production.
Gen3Bio	Gen3Bio is an innovation company transforming waste algae by a proprietary efficient low-cost enzymolysis process to extract fats, sugars, and proteins to produce specialty chemicals.
Inari	Inari, 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.
Insignum AgTech	Insignum AgTech is a developer of biotechnology plants intended to communicate with growers, warning of an early-stage infection so that crops can be protected. The company offers a seed technology that can detect plant diseases or infections early and accurately by turning purple when pathogens begin to infect.

Company Name	Innovation Area Descriptions
Hello Nature (formerly Italtapollina)	Hello Nature 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.
NanoBio Designs	NanoBio Designs is developing a rapid, onsite, and cost-effective DNA testing services for seed suppliers and grain distributors.
Premier Seed Group – Advanced Ag Resources	Advanced Ag Resources is a crop production company that grows, conditions, treats, processes, and packages agricultural seed. Additional services include transportation and warehousing of seed.
Premier Seed Group - 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.
Remington Seeds	Remington Seeds is a seed production company that provides customized seed products to the corn, wheat, and soybean seed industries.
S&G Seeds	S&G Seeds covers a wide variety of services to meet the needs of the seed industry. Included in those services are contract production and conditioning of seeds, fleet services and plastic repair, packaging and repackaging, warehousing, distribution, logistics, and cold storage.
SePRO Corporation	SePRO Corporation develops and manufactures aquatic herbicide products, lawn and turf landscaping products, and greenhouse and nursery 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.
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.
Xylogenics	Xylogenics, uses genetics, molecular biology, and fermentation and applies synthetic biology to deliver value added services and products that enable sustainable chemical production.

## CASE STUDIES: CORTEVA AGRISCIENCE™



Corteva Agriscience™ is a global agricultural company that specializes in developing and providing crop protection and seed solutions to farmers around the world. Corteva Agriscience's product portfolio includes a wide range of agricultural chemicals, such as herbicides, insecticides, and fungicides, as well as seeds for crops such as corn, soybeans, and cotton. The company also provides digital tools and technologies to help farmers optimize their planting and harvesting practices, and to improve their overall productivity and profitability. Formed in 2019 when it split off from DowDuPont, Corteva and its predecessors have been major employers in Indiana for decades.

The enterprise's history in Indiana stems from a prior company, DowElanco, an agribusiness that was formed in 1989 as a joint venture between the Dow Chemical Company and Indiana-based Eli Lilly and Company. Dow, which owned 60 percent, brought expertise in agricultural products to the partnership while Lilly, which controlled 40 percent, had strength in the plant science business.

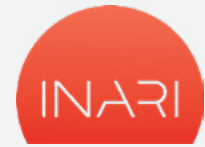
DowElanco located its headquarters in Indianapolis in the 1990s, in part, facilitated by the promise of property tax abatements and infrastructure improvements made near the facility. No manufacturing occurred in Indianapolis however, which primarily housed administration and research facilities. In 1997, Dow bought out Lilly's share of the venture, acquiring full ownership of DowElanco and renaming it Dow Agrosciences. The company underwent many more changes in the 2010s. Dow and DuPont first announced plans to merge in 2015, with plans to spin off into three independent companies. By the next year, the two companies became DowDuPont, and Indianapolis became one of the agricultural division's global business centers. This division was renamed Corteva Agriscience in 2018, and by June 2019, Corteva became an independent entity.

Corteva has maintained a global business center in Indianapolis since spinning out as its own public company but maintained its headquarters in Delaware. In February 2022, the company announced that Indianapolis would be designated as its new global headquarters, effective immediately. "In today's flexible world of work, we have seen clear proof that our dedicated employees can be productive wherever they are," Chuck Magro, chief executive officer of Corteva, said in written remarks. "Designating our Indianapolis location as the Corteva headquarters brings us closer to our operations, our technology, and our customers, while optimizing our flexibility."

Corteva today employs more than 21,000 people worldwide, with approximately 1,400 located in Indiana. Corteva's seed business is primarily based in Iowa, but the company has said much of the innovation in its \$10B global crop protection business is centered in Indianapolis. This business line, which includes numerous advanced herbicides, fungicides, and pesticides, serves over a dozen markets, including corn, soybean, potatoes, rice, and other cereal crops, as well as vegetables and trees.

In an interview on Inside INdiana Business on June 24, 2021, Executive Vice President of Business Platforms Rajan Gajaria stated that the future for Corteva in the Hoosier State is very positive as the company looks to continue its growth. Gajaria indicated that much of the innovation in Corteva's \$15 billion global crop protection business is centered in Indianapolis. He noted that the company's mission of feeding the world has helped bring top talent to Indiana. "We really think that message resonates with people around the world and I'm happy to say that Corteva can attract a lot of talent from across Indiana, from across the U.S. and from across the globe right here to Indianapolis."





## CASE STUDIES: INARI

Founded by Flagship Pioneering in 2016, Inari is disrupting the seed industry by reintroducing genetic diversity to create a more productive and efficient food system. It works by pairing AI-powered predictive design with multiplex gene editing to unlock the full potential of seed by delivering significant increases in yield while simultaneously improving the use efficiency of resources such as water and fertilizer. Inari is developing next-generation seeds that reduce the natural resources required to grow food, while providing farmers with more choice, performance, and value. Inari is headquartered in Cambridge, Massachusetts, but opened its second U.S. location in November 2018 at the Purdue Research Park of West Lafayette, where it has offices, greenhouse space and a farm. It also has operations in Ghent, Belgium.

After a national search, Inari chose the Purdue Research Park to locate the Seed Foundry in 2018, where today it undertakes the seed product development process that taps the natural genetic diversity of plants and works to address major challenges, including climate change. The Seed Foundry is like a factory, but rather than casting metal, the operation inputs Inari's genetic knowledge to produce parent seeds at a faster, more efficient rate.

In an industry where a handful of companies control most assets and distribution channels, the route to market for a new seed tech start-up can be extremely challenging. Inari has chosen to partner with independent seed producers. These relationships assist the company in understanding farmers' needs while offering seed companies and growers an opportunity to help shape the innovation. More importantly, the independent seed dealers are crucial gatekeepers to Inari's target customer base.

Inari believes its technology is unique in that it enables the company to uncover the enormous and largely untapped potential of seeds' natural diversity, helping to reverse seed industry practices of the last 150 years, which have largely focused on increasing yield only. Inari describes its platform as "a whole system of technology" that disrupts the \$54 billion seed industry. The seed industry typically takes 10 years to develop one new seed and delivers less than 1 percent yield increase per year. Inari says its process delivers 20 times better crop performance at one-tenth of the cost and less than one-third of the time.

In the fall of 2022, Inari closed on its latest funding round, bringing the company's total cumulative equity raised to \$475 million. The investment will further advance Inari's leading position in multiplex gene-edited seed technology, support expansion of company product development, and ultimately deliver new value in the commercial seed market.

It has been a little over four years since Inari opened its doors in the Purdue Research Park of West Lafayette. Inari's CEO, Ponsi Trivisvavet, said it didn't take long for the company to experience several clear benefits to operating here.

"It starts with the people," she said. "Considering how important strong diversity of thought is to running an innovation-forward organization and that more than half of our employees are now based in West Lafayette, it is hard to overstate the value of our proximity to the talent pool generated at Purdue University. We already employ nearly two dozen Purdue alumni, and we only expect the number to increase as our company grows." (Purdue Research Foundation, Spotlight on Agriculture, June 24, 2022).

# Agricultural Equipment, Technologies, and Systems

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## What Does This Sector Do?

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, harvesting, and more. In livestock agriculture, additional 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 need 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 computing power, 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 and more productive, 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. Robotics-based automation in the field, as well as in processing facilities, is becoming a reality; and it is anticipated that the development and adoption of automation technologies will continue if not accelerate in search of potential productivity gains.

## Why Is This an Opportunity for Indiana?

*Currently, 53 establishments with 2,663 employees are classified into this innovation sector. Example firms include Advanced Agrilytics, Banjo Corporation, CTB Inc., DTN, EarthWay Products, Equipment Technologies, InsightTRAC, Raven Industries, Soil-Max, Total Control Systems, Traction Ag, Trellis Growing Systems, 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. Additionally, new production methods identified as controlled environment agriculture (CEA) or “vertical farming” continue to push technology into the definition of a farm.

However, the sheer size of U.S. and global agriculture makes the more traditional (though increasingly technology-based) farm machinery and equipment a sizable and important market. For example, the U.S. market for these products is expected to reach sales of \$50.2 billion in 2023 growing to \$53.7 billion by 2029.<sup>17</sup> The increasing use of automation and other computer-based technologies as part of this market will continue to improve farm productivity through improved land usage, more efficient application of seeds, fertilizers, and crop protection methods, and the ability to more precisely predict and measure crop yields. The market for precision agriculture systems and services, including GIS/GPS/GNSS-based data and systems, yield monitors and other sensing devices, variable rate application controllers, guidance and autonomous systems, farm management software, and specialty data management services, is expected to reach U.S. sales of \$4.7 billion in 2023 growing to \$5.1 billion by 2027.<sup>18</sup>

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<sup>17</sup> IBISWorld. Tractors & Agricultural Machinery Manufacturing in the US. January 2023.

<sup>18</sup> IBISWorld. Precision Agriculture Systems & Services. October 2022.

## Recent Innovation Performance: Ag Equipment, Technologies, and Systems

Given the number of smaller, entrepreneurial firms in this platform, especially among emerging precision agriculture-related companies, it is difficult to gauge the entire level of Indiana-based research and product development occurring within this platform. However, it is likely substantial. From a research publication perspective, Purdue University stands out, accounting for 142 of the 165 publications (Table 14). This research was primarily in the fields of agricultural engineering, food science, and remote sensing. The IUPUI Earth Science department is also involved in agricultural-related remote sensing research.

Patent activity in this platform is primarily focused on two areas:

- Animal husbandry/companion animal-oriented products—including more than 20 utility and design patents from Mid-West Metal Products’ pet division (MidWest Homes for Pets), 8 patents to Eco Sports Group (pet training and exercise products), and Rose Acre Farms (for poultry-related enclosures).
- Agricultural equipment—including machinery and engine components led by Indiana-based inventors working for CNH (17 patents), Hydro-Gear (10 patents), and ABI Attachments (3 patents), and pest control devices (Corteva, 8 patents).

**Table 14:** Indiana Agricultural Equipment, Technologies, and Systems Platform - Research and Innovation Output, 2018–2021

<b>Research Publications</b>	<p><b>Total Publications:</b> 165</p> <p><b>Key Disciplines:</b> Agricultural Engineering, Food Science Technology, Agronomy, Multidisciplinary Agriculture, Computer Science-Interdisciplinary Applications, and Remote Sensing.</p> <p><b>Key Corporate Research:</b> Corteva (including Dow AgroSciences and DuPont Pioneer)—4 publications in this platform.</p>
<b>Patents</b>	<p><b>Patents Assigned to Indiana Companies:</b> 134</p> <p><b>Patents Assigned to Indiana Inventors:</b> 177</p> <p><b>Key Corporate Assignees:</b> Mid-West Metal Products—23 in this Platform. Hydro-Gear Limited Partnership—10 in this Platform. Corteva (including Dow AgroSciences and DuPont Pioneer)—11 in this Platform. Eco Sports Group, Inc.—8 in this Platform. Rose Acre Farms, Inc.—7 in this Platform.</p>

Sources: TEconomy analysis using data from Clarivate Analytics’ Web of Science database and Clarivate Analytics’ Derwent Innovation patent analysis database.

Purdue’s research efforts within the Agricultural Equipment, Technologies, and Systems platform were funded, in part, by nearly \$7 million and 11 competitive research awards from the USDA (Table 15). These awards included \$1 million in funding to develop an innovative cyber-framework integrating public/private data for agronomy decision-making. Fort Wayne-based Trellis Growing Systems secured additional SBIR resources from the USDA to continue to develop its modular growing trellis technologies.

From a venture capital perspective, the Agricultural Equipment, Technologies, and Systems platform accounts for \$141 million, or 70 percent of the total venture capital invested in Indiana’s agbioscience firms. Much of this (over \$136 million) is investment in three firms with Indiana operations. With its U.S. headquarters in West Lafayette, Solinftec received \$60 million in later-stage venture investment during the 2018–2021 period to continue product and market development around its real-time agronomy solutions. Taranis, with its U.S. headquarters in Westfield, received \$20 million in Series C (early stage) funding and \$30 million in Series D (later stage) funding to continue to develop its AI-powered crop analytics platform and to expand company operations. Indianapolis-based, Intelinair, received more than \$26 million in two deals during the period.

**Table 15:** Indiana Agricultural Equipment, Technologies, and Systems Platform - Innovation Resources and Capital, 2018–2021

<b>USDA-Funded Research (non-SBIR)</b>	<p><b>Purdue University</b>—11 Awards—\$6,690,731</p> <p><b>University of Notre Dame</b>—1 Award—\$464,340</p> <p><b>State Total</b>—12 Awards—\$7,255,071</p>
<b>SBIR Awards</b>	<p><b>2 Awards</b></p> <p><b>OmniVis (Purdue technology; California company)</b>  2020 Phase I—\$100,000  <i>Covid-19 Rapid Response: A Handheld Diagnostic Device for Covid-19 In Meat and Poultry Processing Facilities</i></p> <p><b>Trellis Growing Systems</b>  2018 Phase II—\$468,818  <i>Low Trellis Production, Harvesting System and Marketing Tools for Locally-Grown Hops and Value-Added Products</i></p>
<b>Angel &amp; Venture Capital</b>	<p><b>Summary</b>  Companies—13  Deals—29  Investment—\$141.00 million</p> <p><b>By Deal Type</b>  Pre-Seed—9 Deals—\$330,000  Angel—1 Deal—\$230,000  Seed—3 Deals—\$1.55 million  Early Stage—10 Deals—\$28.15 million  Later Stage—6 Deals—\$110.74 million</p>

Sources: TEconomy analysis using data from the U.S. Department of Agriculture and SBIR.gov, and Pitchbook venture capital database.

## Companies that are Actively Involved in 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.
Bane Welker Farm Equipment	Bane Welker Farm Equipment offers a wide range of affordable and high-quality farming 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 biowaste into clean fuels.
Cornelius Manufacturing Inc.	Cornelius Manufacturing Inc. 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 Products develops and manufactures high-quality lawn, garden, and ice removal tools. EarthWay holds several patents on the application of liquid and dry 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.

Company Name	Innovation Area Descriptions
GreenMark Equipment	GreenMark Equipment provides farm and agricultural equipment sales and service to farmers, commercial businesses, large property owners, and homeowners.
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.
InsightTRAC	InsightTRAC provides precision robotics that leverages cloud-based data to help growers better manage and optimize their profit per tree. Initially targeting the almond industry, InsightTRAC provides growers with an autonomous winter sanitation solution for what is currently a manual process.
Intelinair	Intelinair is an automated crop intelligence company that leverages AI and machine learning to model crop performance by analyzing high-resolution aerial imagery from aircraft, satellites, and drones.
Iotron	Iotron produces electron beam radiation systems for varied applications including food irradiation.
J&H Consulting	J&H Consulting is a developer of agricultural software intended to forecast yields and improve crop management. The company's agricultural software uses 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.
LeafTech	LeafTech, 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.
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 E. coli 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.
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 has 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 them with the right intervention.
Raven Industries (fka AgSync)	Raven Industries Inc. is a manufacturer of precision agriculture products, high-altitude balloons, plastic film and sheeting, and radar systems.

Company Name	Innovation Area Descriptions
Reynolds Farm Equipment	Reynolds Farm Equipment is a leading equipment dealer serving farmers, homeowners, landscapers, and commercial contractors throughout Indiana
Riley Equipment Inc.	Riley Equipment designs and manufactures processing machinery and bulk material-handling equipment for grain, fertilizer, seed, feed, aggregate mining, and a wide variety of industrial markets.
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.
Smart Guided Systems (aka SmartApply)	Smart Guided Systems manufactures precision guidance systems designed to reduce waste and conserve the environment. The company's density-based sprayer technology cuts pesticide use by more than half, with less waste and higher yields than conventional sprayers.
Soil-Max Inc.	Soil-Max is a manufacturer of tile plows and agricultural drainage products for tiling needs.
Solinftec	Solinftec, a digital precision agriculture company, develops and produces equipment, technology, and systems for the automation of mobile assets and logistics processes.
Taranis	Taranis develops an agriculture intelligence platform that utilizes sophisticated computer vision, data science, and deep learning algorithms to effectively monitor fields. Using state-of-the-art multi-level high-resolution imagery and revolutionary AI and ML capabilities, it offers a full-stack solution for high-precision aerial surveillance imagery to prevent crop yield loss due to insects, crop disease, weeds, and nutrient deficiencies.
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.
Traction Ag LLC	Traction Ag is a farm management software company that helps minimize farm data entry. The software integrates accounting with field operations, resulting in real-time financial analysis for timely, informed decision-making.
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.
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 providing drinkers for broilers and drinkers for layers that can be retrofitted onto an existing watering system without replacing the entire system.

## CASE STUDIES: ADVANCED AGRILYTICS

Advanced Agrilytics Holdings LLC, (Advanced Agrilytics) is a data analytics company that specializes in providing advanced agronomic and precision farming services to farmers and agriculture industry professionals. The company uses a combination of machine learning algorithms, remote sensing technologies, and agronomic expertise to help growers optimize their crop production, increase yields, and reduce costs. Specifically, Advanced Agrilytics delivers independent precision farming advice to row-crop growers, helping growers interpret agronomic data and manage inputs and practices effectively to dramatically increase yields.

Founded in 2013 in Huntington, Indiana, where it still maintains its R&D operation today, Advanced Agrilytics announced in 2020 that it would establish its growing headquarters in Indianapolis. Advanced Agrilytics employs over 100 staff across its Indianapolis, Huntington and Midwest field locations, in careers which include agronomy, data science, software development and project management.

Since its founding, Advanced Agrilytics has accrued significant amounts of efficacy data validating its holistic approach. The company's team of agronomists and scientists have multiple decades of experience in soil science, crop physiology, data science and prescriptive application development. Advanced Agrilytics offers a range of services, including crop modeling and yield forecasting, soil mapping and analysis, variable rate prescription mapping, and crop performance benchmarking. The company uses data collected from a variety of sources, including satellite imagery, weather data, and on-farm sensors, to develop highly detailed, customized insights that can help farmers make more informed decisions about their operations.

One of the company's key strengths is its focus on collaboration and partnership with farmers and other stakeholders in the agriculture industry. Advanced Agrilytics works closely with its clients to understand their specific needs and challenges, and to develop tailored solutions that can help them achieve their goals. By combining cutting-edge technology with deep agronomic expertise and a collaborative approach, Advanced Agrilytics aims to drive innovation and efficiency in the agriculture industry, while also promoting sustainability and environmental stewardship.

Advanced Agrilytics has grown over 300 percent since 2019, with the addition of roles across the business including sales leadership, engineering, data science, research, people development, and operations. Throughout this high-growth period, the team has also experienced over 95 percent customer retention, year over year – indicating the consistent, reliable delivery of on-farm results for its growers.

In January 2023, Advanced Agrilytics announced the collective achievement of reaching one million acres of agronomic influence across its eight-state Midwestern footprint. "Our innovation is being powered by an industry-leading research division in Ag Ingenuity Partners, providing our agronomists with proprietary tools and technology helping to make our science actionable," said Kay Kuenker, CEO. "While this milestone has been achieved by our Grower Direct business segment, it's been the consistent effort from our entire team to get us to this point."





## CASE STUDIES: TARANIS

Taranis, a precision scouting and agricultural intelligence company, has developed an agriculture intelligence platform that utilizes sophisticated computer vision, data science, and deep learning algorithms to effectively monitor fields. By utilizing drone fleets capable of capturing high-resolution imagery, Taranis' proprietary software platform analyzes images and aggregates data to deliver real-time insights during each growth stage at a leaf-level resolution 20 times faster than the manual alternative. The images are tagged and evaluated by Taranis' artificial intelligence platform, which delivers the insights to users through the company's comprehensive CONNECT mobile platform. With Taranis' agronomic solutions, growers and their advisors can detect early symptoms of uneven emergence, nutrient deficiencies, weeds, crop diseases, insects, or water stress almost immediately.

While Taranis was founded in Israel in 2016, it announced its decision to locate its global headquarters in Westfield, Indiana in December of 2020 by consolidating its sales, marketing, and administrative functions at the new Westfield facility. The company chose Westfield to invest nearly \$10.5 million to lease and equip its new 6,000-square-foot facility. The Indiana Economic Development Corporation offered Taranis up to \$1.25 million in conditional tax credits based on the company's high-wage job creation plans. These tax credits are performance-based, meaning the company is eligible to claim incentives once Hoosiers are hired. The company claims that the Indiana site has allowed Taranis to significantly expand its team of agronomists and associates while increasing its total acreage serviced.

"Locating our global headquarters in the heart of America's largest commodity crop production region enables us to interact more directly with our customers to better address the agronomic challenges of their growers," said Mike DiPaola, general manager of North America and vice president of global sales at Taranis. "This exciting chapter for Taranis positions us well for growing our customer base and recruiting employee talent, while also allowing us to entrench ourselves in the area as the undisputed leader in precision scouting" (AgriNovus Indiana, December 10, 2020).

In the fall of 2022, Taranis closed on its latest funding round, bringing the company's total cumulative equity raised to \$99.6 million. Today, Taranis employs more than 120 people, engages with customers around the globe, the company's technology is deployed across more than three million acres.

In January 2023, Taranis announced the launch of AcreForward, a new offering to help ag retailers drive more value from every acre. It provides unprecedented leaf-level insights into growers' crops at higher frequency throughout the season and captures opportunities in every acre, including new insights into soil health and carbon sequestration. AcreForward's new tools, service plans and resources will help advisors deliver high-quality expertise across more fields, engage growers with valuable insights, and get the most out of their Taranis service in the next growing season. Mike DiPaola spoke with Hoosier Ag Today on November 17, 2022 and was quoted as saying: "Indiana really is a great place to have a team and being deeply invested in Indiana has been a really great decision for our company,"

## Animal Health and Nutrition

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### What Does This Sector Do?

The animal health and nutrition platform encompasses basic and advanced nutrition/feed products and 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 platform 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 23 establishments identified as being involved in animal health and nutrition with an employment base of 1,849.*

*Example firms include ADM, BiomEdit, Cook Animal Health, Elanco, United Animal Health, Micronutrients, and Whiteshire Hamroc.*

Increasing the production and quality of livestock for 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 or to 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 impending demand increases without significantly increasing (and in some instances reducing) the land footprint used in production.

The largest component or market for this platform is animal feed. Total U.S. sales of animal feed for both livestock and companion animals are expected to reach \$72.5 billion in 2023, growing to \$74.4 billion in 2028 with companion animal share at 46 percent of this market.<sup>19</sup>

The development of feed supplements designed to improve the health and performance of the animal is a key mechanism in which agbioscience innovation increases productivity and improves quality. 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.

In combination with these feeds or as stand-alone supplements, probiotics for animals continue to increase in importance, especially globally. BCC Research estimates that the total U.S. market for probiotics for animals reached \$1.3 billion in 2022 and is expected to grow by a CAGR of 6.8 percent to \$1.8 billion by 2027. However, the U.S. market only represents about 16 percent of the global market for animal-specific use of probiotics.

Veterinary medicine products constitute the aspects of the platform seeing the highest levels of innovation. According to The Business Research Company, the global animal medicine market (consisting of both veterinary pharmaceuticals and feed additives) will reach \$48.0 billion in 2023, growing at a CAGR of 6.5 percent to \$56.4 billion in 2026.<sup>20</sup> Of this total, veterinary pharmaceuticals account for 53.5 percent of the market value, while feed additives are expected to see a higher overall growth rate of 7.1 percent. The North American market accounts for 48.3 percent (or \$19.9 billion) of the total \$48 billion global market.

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<sup>19</sup> IBISWorld. Animal Food Production in the US. January 2023.

<sup>20</sup> The Business Research Company. Animal Medicine Market Global Briefing 2022: Ukraine-Russia War Impact, September 2022.

U.S. sales of animal health biotech-based products are expected to reach \$10.7 billion in 2023 growing to \$11.3 billion by 2026. Currently, the market is split between drugs and vaccines (41 percent) anti-infectives (33 percent), and other (including genetic breeding tests, DNA and antibody diagnostic tests, and other biotech products) (26 percent).<sup>21</sup>

### Recent Innovation Performance: Animal Health and Nutrition

The animal health and nutrition research platform in Indiana is also one where significant research is performed in academia and corporate research facilities. Purdue University accounts for 631 (75 percent) of the research publications aligned with this platform with both the College of Agriculture (especially the Department of Animal Sciences) and the College of Veterinary Medicine highly engaged in relevant research (Table 16). From a corporate perspective, Elanco Animal Health’s corporate headquarters and key research facilities are also responsible for significant peer-reviewed research accounting for 48 research publications over the 2018–2021 period. Elanco also accounts for half of the Indiana-based patents aligned with this platform.

**Table 16:** Indiana Animal Health and Nutrition Platform - Research and Innovation Output, 2018–2021

<b>Research Publications</b>	<p><b>Total Publications:</b> 843</p> <p><b>Key Disciplines:</b> Agriculture, Dairy &amp; Animal Science, Veterinary Sciences, and Infectious Diseases</p> <p><b>Key Corporate Research:</b> Elanco—48 publications in this Platform. Corteva (including Dow AgroSciences and DuPont Pioneer)—8 publications in this platform (feed related).</p>
<b>Patents</b>	<p><b>Patents Assigned to Indiana Companies:</b> 17</p> <p><b>Patents Assigned to Indiana Inventors:</b> 22</p> <p><b>Key Corporate Assignees:</b> Elanco Animal Health (Lilly)—9 patents in this Platform Audevard—2 patents in this Platform</p>

Sources: TEconomy analysis using data from Clarivate Analytics’ Web of Science database and Clarivate Analytics’ Derwent Innovation patent analysis database.

It should be noted, however, that the significant level of animal health and nutrition research performed in the state does not lead to significant entrepreneurial efforts in the platform as most firms operating within the animal health and nutrition space are major global agribusinesses or significant regional operations, versus newly emerging firms (see Table 17). One emerging company, Verility, a developer of a veterinary medical device using image recognition and artificial intelligence to assist in animal breeding, has received venture support.

<sup>21</sup> IBISWorld. Animal Health Biotechnology in the US. January 2022.

**Table 17: Indiana Animal Health and Nutrition Platform - Innovation Resources and Capital, 2018–2021**

<b>USDA-Funded Research (non-SBIR)</b>	<b>Purdue University</b> —6 Awards—\$3,845,946 <b>State Total</b> —6 Awards—\$3,845,946
<b>SBIR Awards</b>	No Awards
<b>Angel &amp; Venture Capital</b>	<b>Summary</b> Companies—1 Deals—1 Investment—\$ Amount Undisclosed <b>By Deal Type</b> Pre-Seed—1 Deal—\$ Amount Undisclosed

Sources: TEconomy analysis using data from the U.S. Department of Agriculture and SBIR.gov, and Pitchbook venture capital database.

### Companies that are Actively Involved in this Innovation Sector

<b>Company Name</b>	<b>Innovation Area Descriptions</b>
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 a supplier of agricultural products.
BiomEdit, LLC	BiomEdit, LLC is a next-generation animal health company leveraging the science of the microbiome and synthetic biology to introduce novel feed ingredients and medicines to address some of the most challenging conditions in livestock and pets.
Bio Town Ag	Bio Town Ag is operating a sustainable livestock operation, including the use of an anaerobic digester to convert animal waste into energy, fertilizer, and soil. In addition to their own organic wastes and bioproducts, they are bringing organic wastes from other firms increasing the sustainability of those firms.
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 vaccines for pets and livestock.
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.

Company Name	Innovation Area Descriptions
Krishi	Krishi is enabling simpler and lower-cost diagnostics of bovine respiratory disease using low-cost diagnostic sensors built using paper-based materials and isothermal molecular assays.
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.
Premier BioSource	Premier BioSource is an agricultural biosciences company specializing in the production of research-purposed swine.
ReproHealth Technologies, Inc.	ReproHealth Technologies is dedicated to the development of biomedical technology to advanced assisted reproduction in agriculture.
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 to improve environmental sustainability, Tyson Ingredient Solutions produces 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.
Verility	Verility is developing a veterinary medical device that offers animal-side sperm quality checks and ovulation detection by rapidly analyzing cell morphology using image recognition and artificial intelligence, enabling clients to confirm if an animal is ready to enter the breeding herd.
Whiteshire Hamroc	Whiteshire Hamroc is a swine-breeding and genetics company that also produces an innovative building and ventilation system for swine breeding.

# CASE STUDIES: ELANCO ANIMAL HEALTH INCORPORATED



Elanco Animal Health Incorporated (Elanco) is a global animal health company that specializes in developing, manufacturing, and marketing products and services to improve the health and well-being of animals. The company's portfolio includes a wide range of animal health products, including medicines, vaccines, feed additives, and other products for both livestock and pets. Elanco focuses on developing treatments for some of the most harmful diseases in animal health, including ileitis in swine, coccidiosis in poultry, and Bovine Respiratory Disease in cattle, as well as providing products that target common threats of companion animals such as fleas and heartworm disease, and growing medical conditions like separation anxiety.

Elanco has helped shape the animal health industry for more than half a century. The company introduced its first antibiotic for veterinary use in 1953, and today the company offers a diverse portfolio of more than 125 brands to veterinarians and food animal producers in more than 90 countries. With approximately \$4.8 billion in annual sales in 2021, Elanco employs nearly 10,000 people worldwide with approximately 1,400 individuals located in Indiana.

Until 2019, the company was a subsidiary of Eli Lilly and Company, before being divested. After acquiring Bayer's animal health business in 2020, Elanco undertook a rigorous multi-state search for a new global headquarters. It eventually announced Indiana would remain its base for future global consolidated operations, anchored by a new streamlined fit-for-purpose global headquarters in downtown Indianapolis.

In 2022, Elanco unveiled the development's plan in downtown Indianapolis. The planned 220,000 square foot six-story office structure and connected innovation and collaboration buildings will occupy 40 acres of the former General Motors Stamping Plant site on the western edge of the White River, creating a greenspace-forward campus expanding White River State Park.

Elanco's campus is also designed to serve as the foundation of a planned animal health epicenter in Indianapolis. During the unveiling, Jeff Simmons, Elanco president and CEO stated, "We believe Indianapolis is poised to become an epicenter of animal health innovation, and we're excited to be among the architects building its foundation."

The epicenter is expected to include venture studio development "makerspace" and create a scientific discovery network and research clearinghouse that will help position Indiana as a hub for animal health invention.

"Broad access to the world's animals coupled with a laser focus on creating pathways for innovation is what we believe sets Elanco apart as a sought-after partner," continued Simmons. "We're building something significant that will make animals, the city and our world better, and we're designing our new headquarters with those partnerships in mind."

Two such strategic partnerships have already come to fruition. Elanco has announced its initial seed funding to help create and launch Athian in partnership with High Alpha, which was formed to certify, aggregate, and monetize environmental footprint reductions within the food system. Elanco has also announced the creation of BiomEdit, an animal health microbiome innovation company, in partnership with Gingko Bioworks.

Costs associated with this new headquarters are expected to be offset by the competitive incentive packages offered by the State of Indiana and the City of Indianapolis. Construction on the facility is expected to take approximately two to three years to complete.



## CASE STUDIES: UNITED ANIMAL HEALTH

United Animal Health, formally JBS United, was founded in 1956 and is dedicated to providing research-based solutions that create value for its partners in animal agriculture. Specifically, United Animal Health offers livestock nutrition and health products to help protein producers raise healthier animals to feed a growing world globally through the United Animal Health or affiliate brands.

Headquartered in Sheridan, Indiana, team members are positioned around the nation to assist customers with their business needs. United Animal Health, Inc. is now an international company with nine feed mills and research farms across the country. Globally, United Animal Health now extends to 23 countries, including South Korea, the Philippines, and South America. Further, they continue to grow as more employees join to help enable emerging technologies, livestock production, and grain merchandising.

United Animal Health is actively defining the next frontier of technologies relating to animal nutrition and livestock production. United Animal Health is committed to the development of animal nutrition and production technologies designed to bring value to customers. It was one of the first U.S. nutrition companies to invest in its own proprietary research facilities. In fact, research is such a priority that United Animal Health invested half of its assets toward building its first research farm. Today, it owns and operates several production-scale and small-scale discovery research centers. United Animal Health is the only company that owns a pathogen lab, fermentation facility, and research farm for testing. Its research team of scientists and technical support staff focuses on several areas including maximizing production system efficiencies to improve customer profitability. The company's research group applies its findings to commercial settings to develop products that perform in practical environments.

United Animal Health now has more research farms than any other company or organization in the United States, including specific farrow-to-finish research farms, nursery-finish discovery centers, and nutrient management research facilities. The research and development team conducts over 400 trials a year and works in conjunction with several universities, boar studs, and scientists abroad. Along with the development of new feeds, United Animal Health tests genetics, equipment, and management practices.

With headquarters in Sheridan, Indiana, United Animal Health has a unique situation where truck drivers, mill hands, and executives are all in same place. By headquartering in a location adjacent to an active mill, United Animal Health's leadership team notes that everyone in the company through vertical integration "rubs elbows" every day leading to comparative advantage in the marketplace.

# CHAPTER V. MEASURING THE ECONOMIC PERFORMANCE OF INDIANA’S AGBIOSCIENCE INNOVATION PLATFORMS

This chapter further evaluates the employment and economic vitality of Indiana’s agbioscience platforms by comparing the most recent 2018–2021 values and trends with those presented in the prior reports. These values can be used to understand progress across Indiana’s agbioscience industry and to guide the future planning of AgriNovus Indiana.

## Platform Employment Data Used for Impact Analysis

This analysis begins by mapping the entire Indiana agbioscience industry into one of the four innovation platforms (based on industry NAICS codes), and an additional fifth “platform,” representing agricultural production and distribution activities. 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. Through this work, 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) can be assessed.

A key consideration of this assessment of Indiana’s agbioscience industry is the inclusion of specific firm-level employment (gathered through Dun & Bradstreet data or other sources) for those firms identified in Chapter IV that fall outside of the core agbioscience NAICS codes as detailed in Chapter II. For example, Mid-West Metal Products Company is a market leader in the production and development of companion animal and livestock enclosures. However, as a metal products manufacturer, its “official” NAICS code, likely 332618 Other Fabricated Wire Product Manufacturing, is not included in the core agbioscience industry NAICS codes as most firms in this NAICS code do not operate within the agbioscience market. To the extent Indiana’s innovative agbioscience firms identified in Chapter IV do not fall into one of the core agbioscience NAICS codes, they are separately included within the data and IMPLAN modeling based upon their specific industrial sector.<sup>22</sup>

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<sup>22</sup> 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, reached 156,537 workers (and proprietors) in 2021. Hence, even as the industry, state, and country wrestled with the employment and economic implications of the pandemic, **this important sector of the Indiana economy grew by 7.5 percent since 2018**, and by more than 12.8 percent over the course of these performance assessments starting with 2012 data. This is compared to a lesser increase of 2.4 percent in total Indiana private sector employment from 2018 to 2021.

Not surprisingly, and similar to the Chapter II analysis, Agricultural Production and Distribution employs the largest number of Indiana workers and proprietors with more than 74,000 employed in this platform (Table 18). Important for Indiana is the fact that even with the continued structural changes within U.S. agriculture, agricultural production, and distribution, employment has stayed remarkably stable since 2012 and has grown to its highest level since tracking began. Employment captured within this platform accounts for 47.1 percent of the state’s total agbioscience employment (Figure 12).

**Table 18:** Employment and Employment Growth of Indiana’s Agbioscience Platforms (2012–2021)

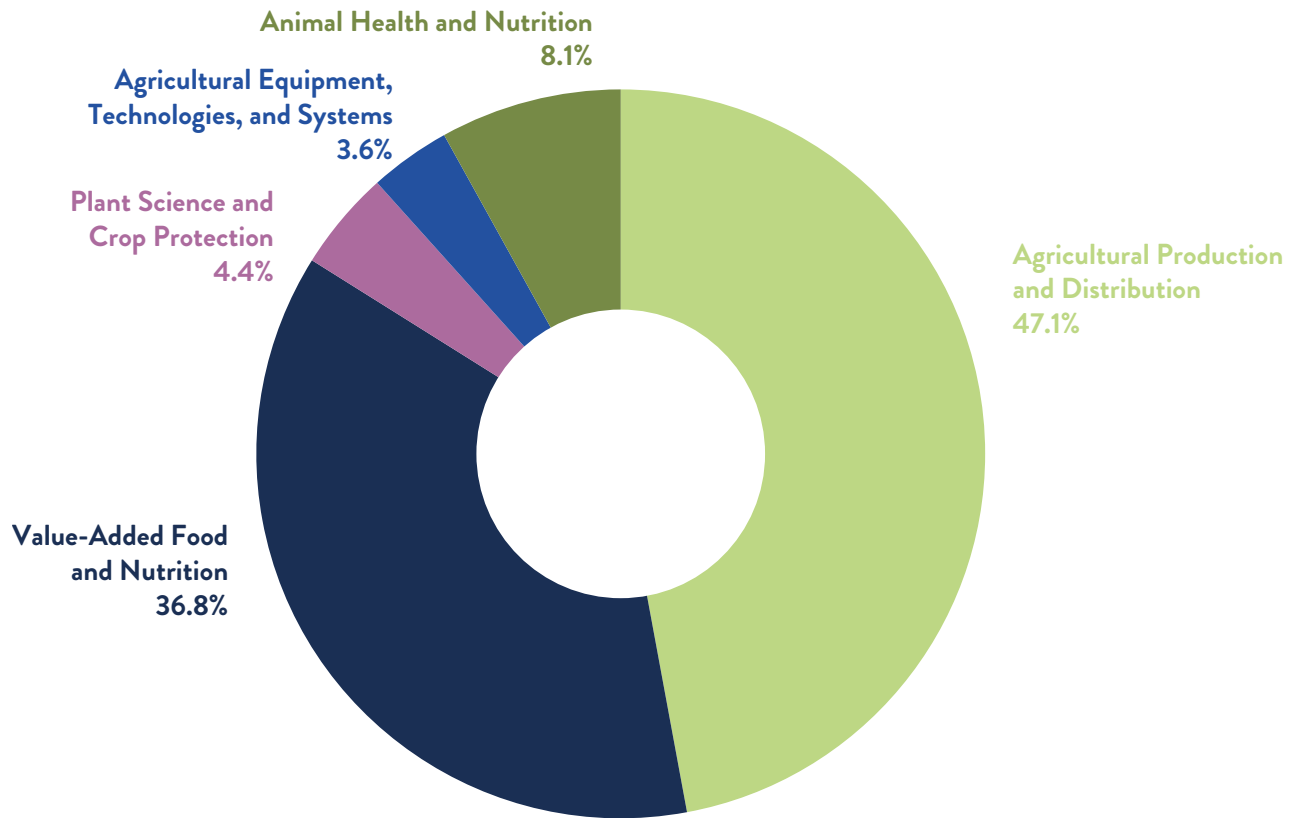
Innovation Platform	Employment				% Employment Change			
	2012	2015	2018	2021	2012–2015	2015–2018	2018–2021	2012–2021
Agricultural Production and Distribution	69,457	70,357	69,431	74,068	1.3%	-1.3%	6.7%	6.6%
Value-Added Food and Nutrition	46,737	50,611	53,393	57,918	8.3%	5.5%	8.5%	23.9%
Plant Science and Crop Protection	7,799	7,548	6,013	6,982	-3.2%	-20.3%	16.1%	-10.5%
Agricultural Equipment, Technologies, and Systems	5,189	5,756	5,474	5,658	10.9%	-4.9%	3.7%	9.0%
Animal Health and Nutrition	9,531	10,030	11,305	12,668	5.2%	12.7%	12.1%	32.9%
Total Indiana Agbioscience Industry	138,713	144,302	145,616	156,537	4.0%	0.9%	7.5%	12.9%

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model. Note: columns will not sum due to eliminating cross-platform duplication.

The Value-Added Food and Nutrition platform has been a historical growth engine for Indiana and continued to grow from 2018 to 2021 by 8.5 percent. At nearly 58,000 workers, this platform accounts for the second-largest level of employment among the five platforms. This most recent growth brings the overall expansion of the platform’s employment to nearly 24 percent from 2012 to 2021. The platform accounts for 36.8 percent of Indiana agbioscience employment as shown in Figure 12.

Approaching 7,000 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, reversed its recent declining trends and increased by over 16 percent from 2018 to 2021. This platform-focused analysis improves upon the employment “accounting” of some corporate entities and related NAICS code changes (e.g., better capturing Corteva’s 2021 Indiana employment). With the February 2022 announcement that Corteva is formally moving its overall headquarters to Indiana from Delaware, this platform may see some employment benefits from these actions in the near future.

**Figure 12:** Agbioscience Platform Shares of Indiana Total Agbioscience Employment (2021)



Source: TEconomy analysis.

The Agricultural Equipment, Technologies, and Systems platform with 5,650 workers is dominated by the distribution of agricultural implements and equipment, primarily to Indiana farmers, accounting for 60 percent of the platform’s employment. From an innovation perspective, this platform also captures the in-state production of agricultural equipment as well as emerging agricultural software and applications providers.

The Animal Health and Nutrition platform accounts for over 12,600 jobs and represents 8.3 percent of Indiana agbioscience employment. While it is unique, with the inclusion of Elanco’s Indiana operations, it is dominated by the broadly defined and growing Veterinary Services component that includes both livestock and companion animal services and accounts for 78 percent of the platform’s employment.

## 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 updated 2021 analysis, the State of Indiana 2021 model was developed representing the activities (as measured by employment) for the five platforms. Data for 2012, 2015, and 2018 developed in the prior analysis were put into 2021 dollars using inflation adjustment factors from the IMPLAN model.

### 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 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.

This I-O analysis effectively models multiplier effects (also known as “ripple effects”) that originate from agbioscience company expenditures in the Indiana economy. In this instance, the model is “driven” by known direct employment levels. The model then estimates direct output and expenditures from this employment. The IMPLAN I-O model is then 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). It consists of Output minus the costs of all purchased inputs included wages, benefits, and taxes.
- **Government Revenues** includes estimates of revenues generated for local/county, state, and federal governments through the economic activity measured. It should be noted that government revenue metrics do not include “multiplier” calculations.

Table 19 shows the output estimated by the IMPLAN model for all four periods in 2021 dollars to better understand the real (versus inflationary) change over time. Among the five Indiana platforms, three platforms exhibited “real” double-digit output growth over the 2018–2021 period, with four showing real output growth over the entire 2012–2021 period.

**Table 19:** Estimated Real Output and Real Change in Output of Indiana’s Agbioscience Platforms (2012–2021)

Innovation Platform	Output (in 2021 dollars; \$M)				% Real Output Change			
	2012	2015	2018	2021	2012–2015	2015–2018	2018–2021	2012–2021
Agricultural Production and Distribution	\$12,700.0	\$12,379.9	\$13,210.1	\$17,061.7	-2.5%	6.7%	29.2%	34.3%
Value-Added Food and Nutrition	\$26,071.9	\$28,575.9	\$29,458.1	\$29,963.1	9.6%	3.1%	1.7%	14.9%
Plant Science and Crop Protection	\$5,507.6	\$5,502.8	\$3,104.5	\$3,329.5	-0.1%	-43.6%	7.2%	-39.5%
Agricultural Equipment, Technologies, and Systems	\$1,638.6	\$2,045.9	\$1,895.0	\$2,214.2	24.9%	-7.4%	16.8%	35.1%
Animal Health and Nutrition	\$4,008.8	\$4,085.9	\$4,353.6	\$5,541.3	1.9%	6.6%	27.3%	38.2%
Total Indiana Agbioscience Industry	\$49,926.9	\$52,590.3	\$52,021.2	\$58,104.4	5.3%	-1.1%	11.7%	16.4%

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

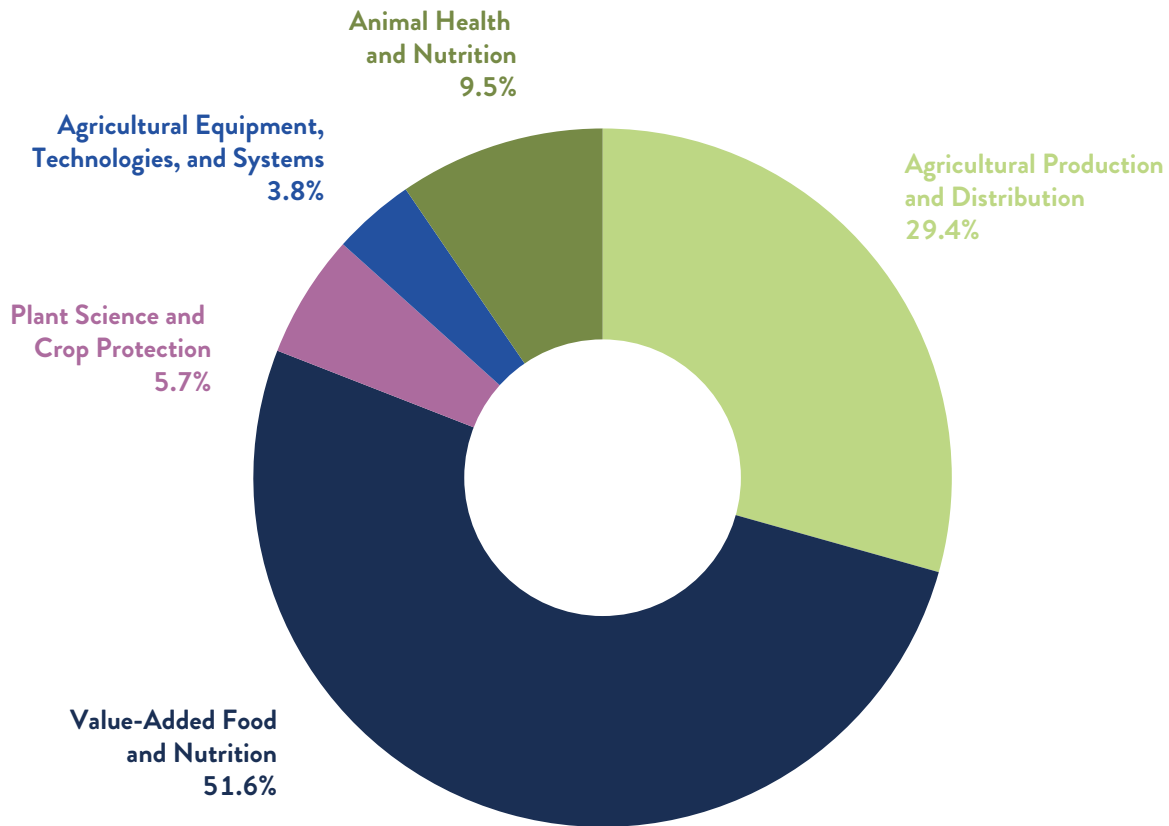
A significant increase of over \$3.8 billion (29.2 percent) from 2018 to 2021 in Indiana’s farmgate proceeds from Agricultural Production and Distribution yielded an annual output of over \$17 billion in 2021.<sup>23</sup> Additionally, with a slight increase in output compared to 2018, the Value-Added Food and Nutrition platform, reached nearly \$30 billion in sales in 2021—accounting for the largest share of Indiana’s agbioscience sales at 51.6 percent (Figure 13).

Agricultural Equipment, Technologies, and Systems platform output realized a trend reversal in the current period going from a 7.4 percent decline from 2015–2018 to a 16.8 percent increase from 2018–2021. However, much of the growth has come from traditional agricultural machinery manufacturers and wholesalers, versus the smaller, software/computer-oriented precision agriculture firms.

<sup>23</sup> Readers are reminded that this value consists only of the crop and livestock aspects of “agriculture.” This analysis does not include forestry output.

Though representing only 9.9 percent of the total agbioscience economic output, continued and accelerating real growth is shown within the Animal Health and Nutrition platform as it has achieved the largest output growth rate over both the recent 2018–2021 and the full 2012–2021 periods, 27.2 percent, and 38.2 percent respectively.

**Figure 13:** Agbioscience Platform Shares of Indiana Total Agbioscience Output (2021)



Source: TEconomy analysis using IMPLAN 2021 State of Indiana model.

The Plant Science and Crop Protection platform’s output results showed an increase of 7.2 percent from 2018–2021. These results continue to be affected by and reflect a combination of stand-alone research and administrative operations that can show lower output if this revenue is captured elsewhere within the corporate structures. For example, the evolving landscape in Indiana with Corteva corporate activities could be impacting these data. Again, the February 2022 announcement that Corteva would be moving its full headquarters to Indiana, may see clarification of some of these data in the future.

While the input-output models allow for the estimation and examination of platform-specific output, the overall economic value or impact on the state of each platform, and ultimately the entire Indiana agbioscience industry, can also be assessed. The following provides the details of an economic impact analysis of each of the five Indiana agbioscience industry platforms as distinct, stand-alone platforms. Due to the specific definitional and firm inclusion aspects of each platform, certain cross-platform double counting is removed when developing and providing the summary economic impact analysis for the combined Indiana agbioscience industry.

## Agricultural Production and Distribution

The full impact analysis of the Indiana Agricultural Production and Distribution platform (Table 20) reveals a total economic impact of nearly \$30 billion when capturing the direct platforms output; sales of in-state suppliers; and Indiana workers, including farm proprietors, spending their wages on personal consumption.<sup>24</sup>

This performance yields an output multiplier of 1.76—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 \$0.76 throughout the broader Indiana economy.

**Table 20:** Economic Impact of Indiana’s Agricultural Production and Distribution Platform (2021)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	Local/County Tax Revenue (\$M)	State Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	74,068	\$4,744.17	\$6,649.39	\$17,061.67	(\$60.48)	\$29.66	\$839.58
Indirect Effect	26,116	\$2,020.93	\$3,318.15	\$7,046.17	\$86.54	\$198.88	\$337.57
Induced Effect	35,144	\$1,959.89	\$3,367.46	\$5,863.20	\$118.11	\$243.75	\$243.89
Total Impact	135,328	\$8,724.99	\$13,335.00	\$29,971.0	\$144.17	\$472.29	\$1,421.04
Multiplier	1.83	1.84	2.01	1.76			

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model. Negative tax revenue numbers indicate instances when subsidies and other government payments were larger than tax revenues generated.

Similarly, these economic activities, corresponding to the 74,000 Hoosiers direct platform workers, support an additional 61,000 workers throughout the state.

<sup>24</sup> Typically, when economic research reports discuss the “total impact” of a project, firm, or industry, they are referring to the total output impacts.

## Value-Added Food and Nutrition

Indiana's Value-Added Food and Nutrition Platform (Table 21) is the largest platform in terms of both direct output and total impacts, reaching more than \$49 billion in 2021. This level of economic activity generates and supports a total employment impact of nearly 162,000 Indiana workers, giving the Platform the largest employment multiplier of any of the five platforms of 2.80. Every direct Platform job generates and supports an additional 1.80 jobs in the state of Indiana. Importantly, this platform, including its Indiana supply chain and workers, returns \$1.36 billion to the state in the form of local/county and state tax revenues.

**Table 21:** Economic Impact of Indiana's Value-Added Food and Nutrition Platform (2021)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	Local/County Tax Revenue (\$M)	State Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	57,918	\$3,840.30	\$7,863.88	\$29,963.10	\$175.80	\$396.97	\$793.56
Indirect Effect	65,396	\$4,391.22	\$6,459.46	\$14,667.37	\$108.15	\$283.98	\$786.09
Induced Effect	38,594	\$2,152.04	\$3,692.13	\$6,395.61	\$129.10	\$266.41	\$267.74
Total Impact	161,908	\$10,383.57	\$18,015.46	\$51,026.09	\$413.05	\$947.36	\$1,847.39
Multiplier	2.80	2.70	2.29	1.70			

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model.

## Plant Science and Crop Protection

The impact analysis of the Plant Science and Crop Protection platform (Table 22) estimates total output impacts of nearly \$5.4 billion in 2021. This platform also is characterized by a significant employment multiplier. The economic activities surrounding the Platform's direct employment of nearly 7,000 workers generate and support over 11,000 additional Indiana jobs—for every Platform job, an additional 1.6 jobs are created throughout the Indiana economy (employment multiplier of 2.60).

**Table 22:** Economic Impact of Indiana's Plant Science and Crop Protection Platform (2021)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	Local/County Tax Revenue (\$M)	State Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	6,982	\$626.06	\$1,464.27	\$3,329.47	\$73.01	\$138.24	\$106.93
Indirect Effect	6,341	\$437.54	\$649.76	\$1,243.03	\$17.76	\$39.62	\$78.80
Induced Effect	4,839	\$270.35	\$463.66	\$808.52	\$16.30	\$33.63	\$33.63
Total Impact	18,162	\$1,333.95	\$2,577.69	\$5,381.01	\$107.07	\$211.49	\$219.36
Multiplier	2.60	2.13	1.76	1.62			

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model.

## Agricultural Equipment, Technologies, and Systems

Though the smallest of the five platforms in terms of total economic impact, the Agricultural Equipment, Technologies, and Systems platform (Table 23) still generates a total economic (output) impact of more than \$3.6 billion.

**Table 23:** Economic Impact of Indiana’s Agricultural Equipment, Technologies, and Systems Platform (2021)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	Local/County Tax Revenue (\$M)	State Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	5,658	\$509.21	\$914.83	\$2,214.24	\$20.36	\$46.79	\$101.51
Indirect Effect	4,056	\$278.88	\$406.46	\$797.19	\$9.88	\$22.83	\$51.59
Induced Effect	3,652	\$203.97	\$349.79	\$609.98	\$12.30	\$25.37	\$25.37
Total Impact	13,366	\$992.06	\$1,671.08	\$3,621.42	\$42.54	\$94.99	\$178.48
Multiplier	2.36	1.95	1.83	1.64			

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model.

## Animal Health and Nutrition

As discussed, the employment and thus economic impacts of the Animal Health and Nutrition platform (Table 24) are significantly influenced by the substantial veterinary medicine services aspect of the Platform’s employment. Though the platform is the third largest among the five in terms of total employment and total output impacts, its services-dominated nature generates the smallest output multiplier (1.52) among the five platforms.

**Table 24:** Economic Impact of Indiana’s Animal Health and Nutrition Platform (2021)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	Local/County Tax Revenue (\$M)	State Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	12,668	\$941.01	\$2,517.61	\$5,541.31	\$58.57	\$128.12	\$200.19
Indirect Effect	6,952	\$499.58	\$763.76	\$1,806.80	\$5.33	\$21.54	\$96.50
Induced Effect	6,571	\$366.93	\$629.44	\$1,097.22	\$22.11	\$45.63	\$45.65
Total Impact	26,190	\$1,807.52	\$3,910.81	\$8,445.32	\$86.02	\$195.29	\$342.34
Multiplier	2.07	1.92	1.55	1.52			

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model.



## Total Agbioscience Industry

Together, Indiana’s five agbioscience platforms (Table 25 and Figure 14), have a combined direct output of more than \$58 billion, and together generate and support more than \$91 billion in total economic impact in the state of Indiana. In terms of the agbiosciences contribution to the gross state product (GSP) of Indiana, the industry accounts for over \$19 billion in direct contribution and ultimately supports over \$37 billion in GSP. These figures represent 5 percent and 9 percent, respectively, of Indiana’s total GSP.<sup>25</sup>

This agbioscience combined economic activity in concert with the combined platforms’ employment of more than 156,500 jobs supports a total of nearly 328,000 jobs in Indiana—for every direct Indiana agbioscience job, 1.10 additional jobs are supported in the state.

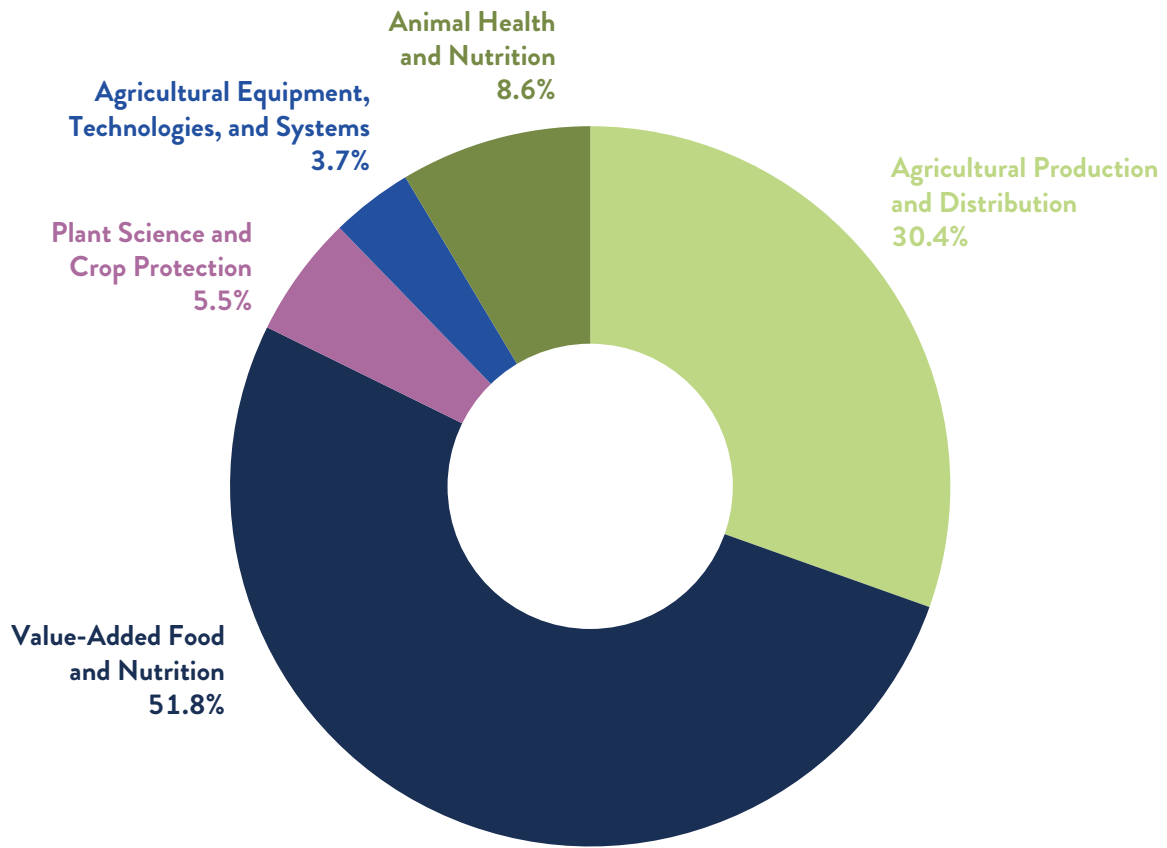
**Table 25:** Economic Impact of Indiana’s Total Agbioscience Industry (2021)

Impact Type	Employment	Labor Income (\$M)	Value Added (\$M)	Output (\$M)	Local/County Tax Revenue (\$M)	State Tax Revenue (\$M)	Federal Tax Revenue (\$M)
Direct Effect	156,537	\$10,644.31	\$19,397.50	\$58,104.37	\$265.97	\$736.23	\$2,031.96
Indirect Effect	83,142	\$6,177.06	\$9,509.78	\$18,624.94	\$168.43	\$417.54	\$1,088.30
Induced Effect	88,280	\$4,929.89	\$8,464.76	\$14,653.92	\$295.75	\$610.30	\$613.39
Total Impact	327,958	\$21,751.26	\$37,372.04	\$91,383.23	\$730.15	\$1,764.07	\$3,733.65
Multiplier	2.10	2.04	1.93	1.57			

Source: TEconomy analysis using IMPLAN 2021 State of Indiana model.

<sup>25</sup> State GDP as measured and supplied by the 2021 Indiana IMPLAN model.

**Figure 14:** Agbioscience Platform Shares of Indiana Total Agbioscience Economic Impact (2021)



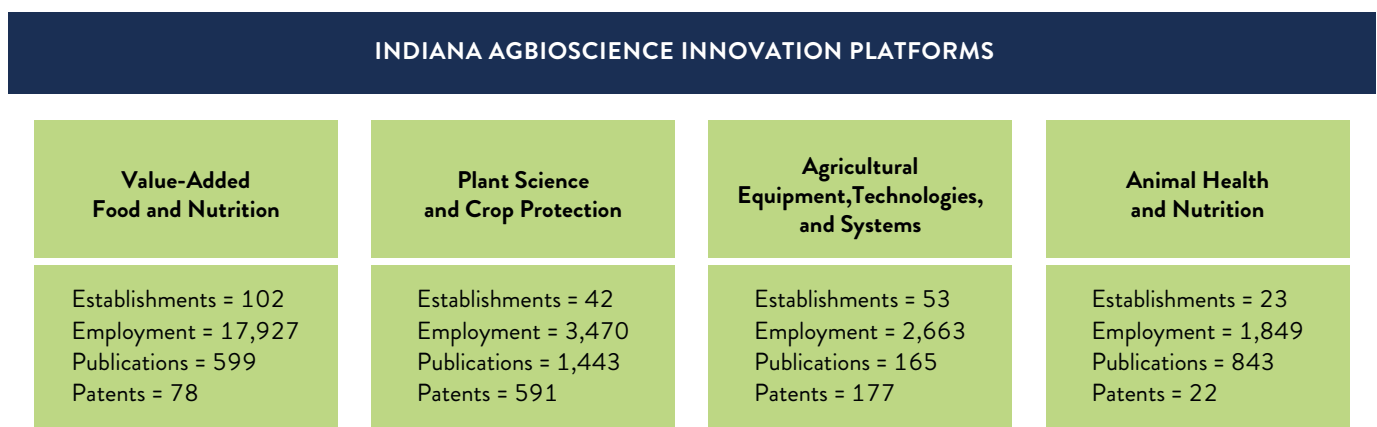
Source: TEconomy analysis using IMPLAN 2018 State of Indiana model.

# CHAPTER VI. CONCLUSIONS

Indiana’s agbioscience industry continues to be a key and growing industry for the state, representing continued opportunities for economic growth. TEconomy’s updated analysis for AgriNovus Indiana finds that inclusive of agricultural production, the agbioscience cluster directly employed more than 145,000 Hoosiers in 2021. While farm proprietors’ employment continues to slowly decline, the “industrial” sectors and subsectors of Indiana’s agbioscience industry grew by 4.6 percent, reaching 97,000 employees in 2021. When combined with primary production, overall employment grew at 2.4 percent, mirroring Indiana’s total private sector employment growth. Agbioscience is also notable in providing average wages that are higher than the average private-sector wage in Indiana. Agbioscience sector wages averaged \$69,368 in 2021, which is higher than the average Indiana private-sector wage of \$67,328.

Indiana’s agbioscience industrial growth is driven by the four key innovation platforms illustrated in Figure 15. Each of the four platforms is a focus point of significant innovation activity in Indiana as indicated by the publication and patent statistics. The platforms also are composed of a significant base of industry establishments, ranging from a high of 102 establishments in the Value-Added Food and Nutrition platform to a low of 23 establishments in the Animal Health and Nutrition platform. Together, there are 25,909 personnel employed in the innovative companies driving these platforms, with the largest concentration being in the Value-Added Food and Nutrition platform (17,927 personnel, 69.2 percent of all platform employment).

**Figure 15:** Indiana Agbioscience Innovation Platforms Summary



Source: TEconomy Partners, LLC.

The use of input/output analysis serves to demonstrate the current economic importance of Indiana's agbioscience platforms. Indiana's agbioscience platforms realized significant growth over the 2018–2021 period. As a result, **Indiana's agbioscience industry generated and supported more than \$91 billion in total economic impact in the State of Indiana in 2021** compared to \$76 billion in 2018. It is found that all platforms increased their employment and output economic impacts between 2018 and 2021. The agbioscience industry's combined economic activity in concert with the combined platforms' employment supports a total of nearly 328,000 jobs in Indiana. For every direct agbioscience job, 1.10 additional jobs are supported in Indiana.

AgriNovus Indiana seeks to create the conditions necessary to fuel the growth of Indiana's agbioscience sector, ensuring its long-term economic sustainability and global competitiveness. As such, AgriNovus Indiana has grown to become a signature economic development initiative for Indiana, providing a wide range of value-added programs and services for the agbioscience industry of Indiana. With the state experiencing sizeable economic growth in all four of the AgriNovus Indiana targeted agbioscience platforms it appears that Indiana is well positioned for future growth driven by agbioscience innovation.

# APPENDIX A. NAICS CODES DEFINING AGBIOSCIENCES

Supersector	Major Subsector	NAICS Code	NAICS Description
Ag & Biological 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 Mfg.
		333210	Sawmill & Woodworking Machinery Mfg.
		333291	Paper Industry Machinery Mfg.
		333294	Food Product Machinery Mfg.
		423820	Farm/Garden Machinery & Equipment Wholesale
	Agricultural Chemicals	325311	Nitrogenous Fertilizer Mfg.
		325312	Phosphatic Fertilizer Mfg.
		325314	Fertilizer (Mixing Only) Mfg.
		325320	Pesticide & Other Agricultural Chemical Mfg.
	Agricultural Inputs Wholesaling	424910	Farm Supplies Merchant Wholesalers
Veterinary Medicines & Vaccines	325412AG	Pharmaceutical Preparation Mfg. (veterinary medicines only)	
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 Processing	311212	Rice Milling
		311213	Malt Mfg.
		311221	Wet Corn Milling
		311222	Soybean Processing
		311223	Other Oilseed Processing
		311225	Fats & Oils Refining & Blending
		311311	Sugarcane Mills
311312	Cane Sugar Refining		
311313	Beet Sugar Mfg.		

Supersector	Major Subsector	NAICS Code	NAICS Description	
Primary Production (cont.)	Biomass Processing	321113	Sawmills	
		322110	Pulp Mills	
		325193	Ethyl Alcohol Mfg.	
Food, Nutrition, & Health	Beverage Manufacturing	312111	Soft Drink Mfg.	
		312112	Bottled Water Mfg.	
		312113	Ice Mfg.	
		312120	Breweries	
		312130	Wineries	
		312140	Distilleries	
	Drugs & Diagnostics	325411	Medicinal & Botanical Mfg.	
		325413	In-Vitro Diagnostic Substance Mfg.	
		325414	Biological Product (except Diagnostic) Mfg.	
	Food Processing & Manufacturing	3111	Animal Food Mfg.	
		3113	Sugar & Confectionery Product Mfg.	
		3114	Fruit/Vegetable Preserving & Specialty Food Mfg.	
		3115	Dairy Product Mfg.	
		3116	Animal Slaughtering & Processing	
		3117	Seafood Product Preparation & Packaging	
		3118	Bakeries & Tortilla Mfg.	
		3119	Other Food Mfg.	
		311230	Breakfast Cereal Mfg.	
		Wholesaling, Distribution, & Storage Operations	Agricultural Commodity Wholesaling	42452
	424590			Other Farm Product Raw Materials Wholesale
Food Product Wholesaling	424430		Dairy Product Wholesale	
	424440		Poultry Product Wholesale	
	424470		Meat & Meat Product Wholesale	
	424480		Fruit & Vegetable Wholesale	
Warehousing and Storage	493120		Refrigerated Warehousing & Storage	
	493130		Farm Product Warehousing & Storage	

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





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