

# The Research Landscape for *Feeding the Planet Sustainably*

# Executive Summary

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## Purpose

This work was commissioned to provide insight into research that has been conducted towards the goal *Feeding the Planet Sustainably* overall and specifically within fields related to biotechnology and agriculture. The analyses will endeavor to provide insight into how much research has been done, who the global leaders in the research areas are, what sectors are leading the research, and how the research is being used to support other research and innovations.

## Scope

Bibliometric analyses were based on peer-reviewed publications (articles, reviews, and conference papers) and focused on the period 2001–2020. The source for all bibliometric data was the Scopus database. Scopus includes data and linkages across 82 million items from 80 thousand affiliations and 17 million authors. It is the largest curated abstract and citation database of peer-reviewed literature and provides a comprehensive view on the research landscape.

## Defining the research area

Research that supports the goal Feeding the Planet Sustainably was mapped to the United Nations Sustainable Development Goal (SDG) 2: *Zero Hunger – End hunger, achieve food security and improved nutrition and promote sustainable agriculture*. The query for defining this research was developed previously and consists of over 1,000 independent queries developed to address the specific targets and indicators related to this goal.<sup>1</sup> Table 1 shows the three research subcategories of interest within SDG 2 and how they were defined using queries.

Subcategory name	Query terms
<b>Traditional breeding strategies</b>	GWAS OR "Genome Wide Association Study" OR qtl OR "Quantitative Trait Loci" OR haploid OR phenotyp* OR genotyp* OR transgen*
<b>Biotechnology (experimental)</b>	"Synthetic biology" OR "Gene edit" OR engineering OR genomic*
<b>Biotechnology (computational)</b>	robotic* OR sensors OR computation OR "Machine Learning" OR "Artificial Intelligence" OR model* OR predict*

Table 1 – Subcategories of interest and the query terms used to identify the relevant research.

<sup>1</sup> Methodology and the full query for SDG 2 research can be accessed here: <https://data.mendeley.com/datasets/9sxdykm8s4/3>.

The results retrieved using the queries in Table 1 were validated by the subject matter expert coordinating the workshop.

## Results

### Research Landscape for *Feeding the Planet Sustainably*

Research supporting the goal *Feeding the Planet Sustainably* spans many concepts. Figure 1 shows the 50 most prevalent keyphrases<sup>2</sup> represented in the publication set. The keyphrase *Food Security* features most prominently in the publication set, while *Malnutrition* and *Agriculture* feature as the second and third most highly represented keyphrases, respectively. Figure 2 provides insight into the subject areas under which the publications fall and the research Topics<sup>3</sup> most highly represented in the research. These data show that research related to *Feeding the Planet Sustainably* mainly falls within the subject areas of agriculture, environmental sciences, and medicine. The largest Topics represented within the research are indicated in Figure 2 and Table 2. Figure 3 shows the visualization of the co-clustering of terms that appear in the titles and abstracts, which provides further insight into the research represented within the area *Feeding the Planet Sustainably*. The co-clustering of terms reveals five major themes in the research, three of which are related to agriculture.



Figure 1 – Top 50 keyphrases represented in the Research Area “SDG 2: Zero Hunger”.  
Source: Scopus and SciVal

<sup>2</sup> The Elsevier Fingerprint Engine is employed to extract distinctive keyphrases within the Research Area. The text mining is done by applying a variety of Natural Language Processing techniques to the titles and abstracts of the documents in the Research Area in order to identify important concepts. Concepts are matched against a set of thesauri spanning all major disciplines. For each document the distinctive keyphrases are selected based on Inverse Document Frequency (IDF), by incorporating a factor that diminishes the weight of words that occur frequently in the document set and increasing the importance of words that occur rarely. Each keyphrase is given a relevance between 0 and 1 with 1 given to the most frequently occurring keyphrase. Remaining keyphrases are given a value based on their relative frequency.

<sup>3</sup> Topics refers to publication sets created using citation patterns of Scopus-indexed publications. The methodology for using citation patterns to define research Topics was developed through an Elsevier collaboration with research partners (Klavans, R., & Boyack, K. W. 2017. Research portfolio analysis and Topic prominence. *Journal of Informetrics*, 11, 1158–1174.). The advantage of taking a citation-based approach to identify research Topic is that one need not rely on identifying all the relevant keywords to define a research area. Rather, the research area is delineated by citation patterns in the Topic, whereby research that appears in the same citation network is clustered together in the same Topic. This approach provides a more nuanced definition of the research Topic.

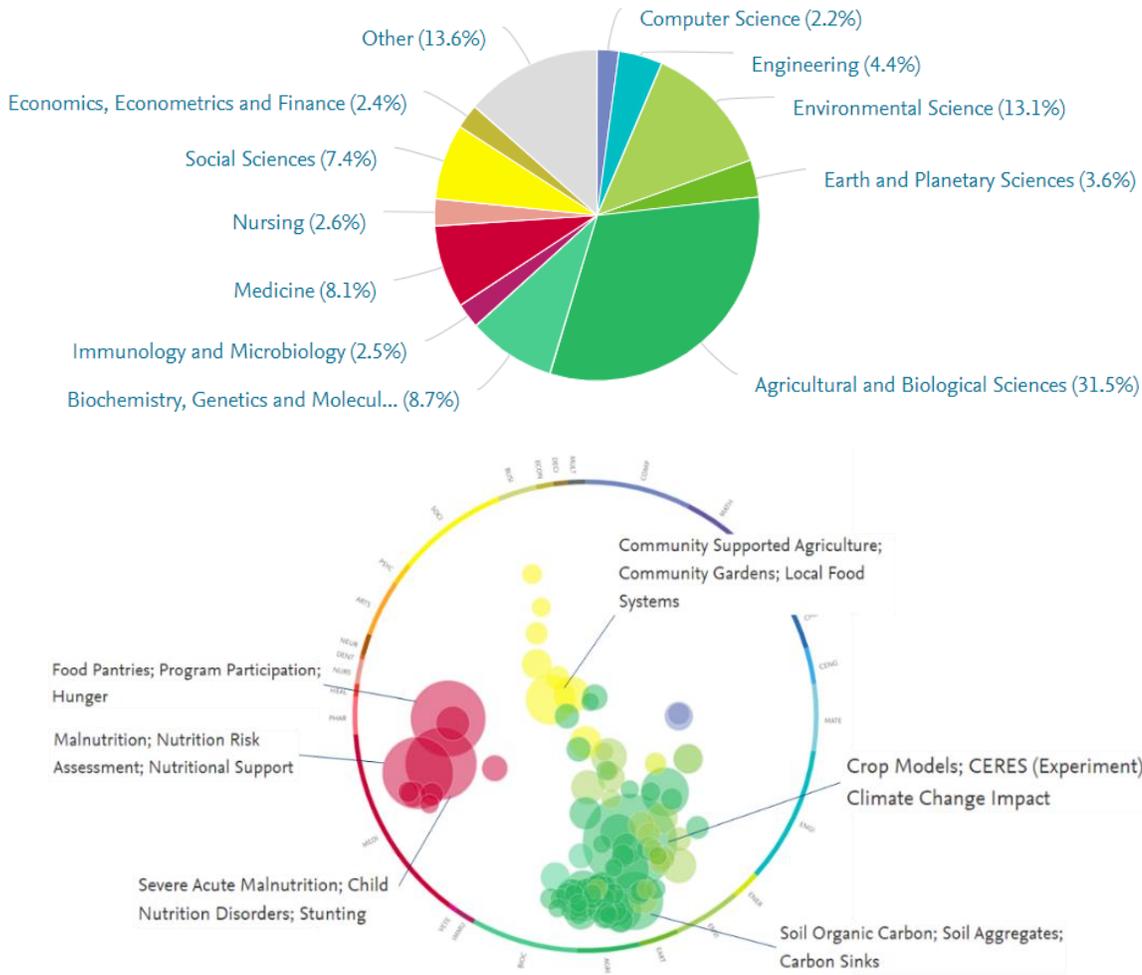


Figure 2 – Top: Distribution of research publications from 2011–2020 in the Research Area “SDG 2: Zero Hunger” across subject areas. Bottom: Distribution of publications within Topics from 2011-2020 in the Research Area “SDG 2: Zero Hunger”. Source: Scopus and SciVal



Research that contributes to the goal *Feeding the Planet Sustainably* has grown markedly over the past two decades, as shown in Figure 4. While in 2001, 0.7% of all research related to the *Feeding the Planet Sustainably* goal, this value has since doubled with 1.4% of all research in 2020 relating to this goal. This represents a compound annual growth rate (CAGR) over the past two decades of 9.6%, which is four percentage points higher than the growth rate of research overall (CAGR = 5.6%). From 2001-2020, 394,414 publications were published in this research area.

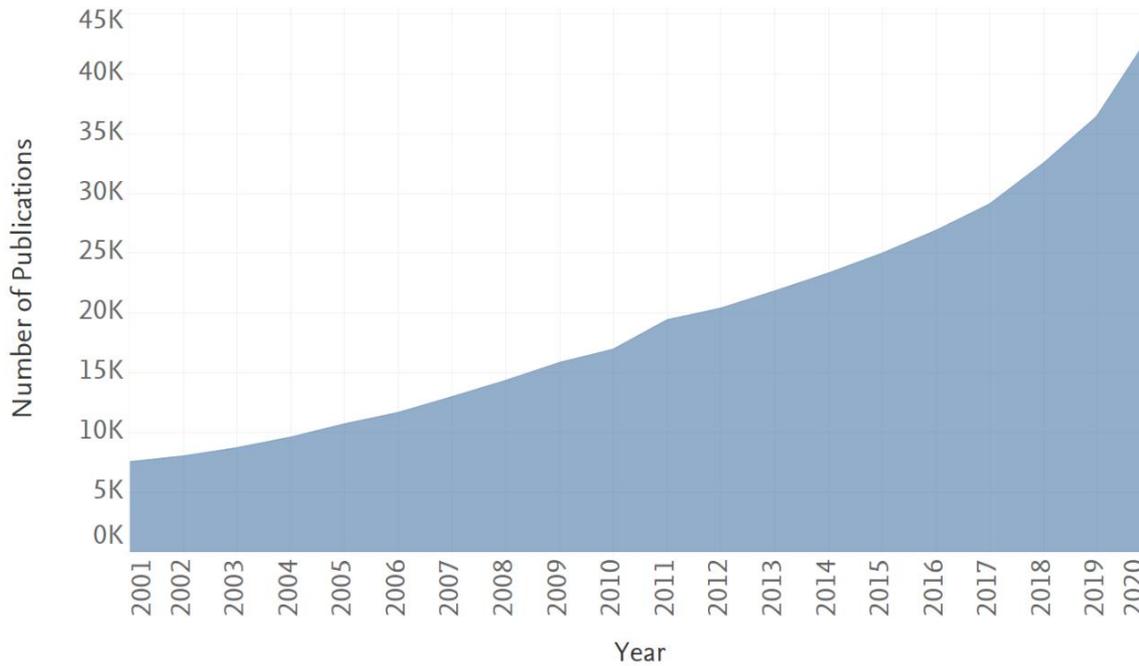


Figure 4 – Number of publications on Feeding the Planet Sustainably, 2001–2020.  
Source: Scopus

Figure 5 shows the top 15 regions contributing to *Feeding the Planet Sustainably* research. The United States leads in this respect, having contributed to 89,945 publications over the past two decades. China follows with contributions to 47,365 publications. Beyond absolute publication count, the percentage of all research being focused on the *Feeding the Planet Sustainably* goal provides clues about regional prioritization strategies. These data show that although the United States contributed to the highest number of publications to *Feeding the Planet Sustainably*, Brazil, India, and Australia dedicated more of their overall research efforts in this area with *Feeding the Planet Sustainably* research representing 2.4%, 1.7%, and 1.5% of their research output, respectively. In contrast, 0.9% of the United States research output related to the *Feeding the Planet Sustainably* goal.

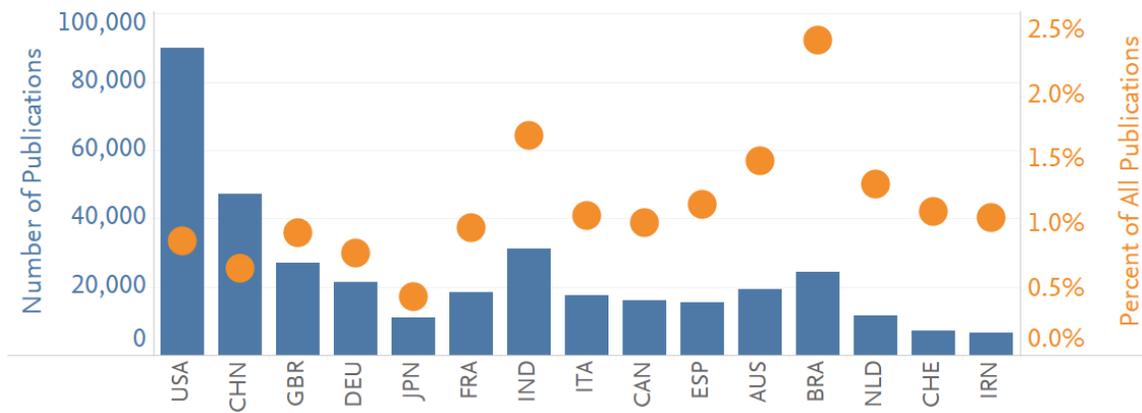


Figure 5 – Number of Feeding the Planet Sustainably research publications from each region and percent of the research portfolio represented by Feeding the Planet Sustainably research published 2001–2020.  
Source: Scopus

Table 3 shows the contribution to research publications over the last five years (2016–2020) disaggregated by cross-sectoral collaboration type. The data show that 89% (164,845) of all publications involved some contribution from academic institutions, with 29% of those publications resulting from collaboration with a government entity, 27% resulting from collaboration with a non-governmental organization (NGO), and 2% resulting from collaboration with a corporate entity.

Collaboration type	Scholarly output
Academic	85,287
Academic-Government	33,082
Academic-NGO	29,532
Academic-Government-NGO	14,210
Government	6,632
NGO	6,021
Government-NGO	2,324
Academic-Corporate	1,255
Academic-Corporate-NGO	748
Academic-Corporate-Government	731
All Sectors	648
Corporate	318
Corporate-NGO	204
Corporate-Government	112
Corporate-Government-NGO	69

Table 3 - *Feeding the Planet Sustainably* research publications from 2016–2020 categorized according to the sectors represented in the author byline.

Source: Scopus

Biotechnology research towards the goal *Feeding the Planet Sustainably*

Figure 6 shows that biotechnology research contributes greatly to the goal *Feeding the Planet Sustainably*, with research using the approaches of computational biotechnology, traditional breeding, and experimental biotechnology representing 23%, 12%, and 5% of the globally published *Feeding the Planet Sustainably* research, respectively. In the US, these subcategories represent a slightly higher percent of the *Feeding the Planet Sustainably* research portfolio, with 28% of US research using a computational biotechnology approach, 13% of US research employing a traditional breeding approach, and 6% of US research employing an experimental biotechnology approach. The percentages of research falling within biotechnology areas has been consistent over the last two decades (2001–2020) both globally and in the United States, with a few exceptions. Globally, research employing computational biotechnology approaches has gained higher representation; it now represents 27% of *Feeding the Planet Sustainably* research, up from 15% in 2001. In the United States, research employing computational biotechnology approaches represented 19% of *Feeding the Planet Sustainably* research in 2001; this value has increased by 13 percentage points over two decades, to 32% in 2020.

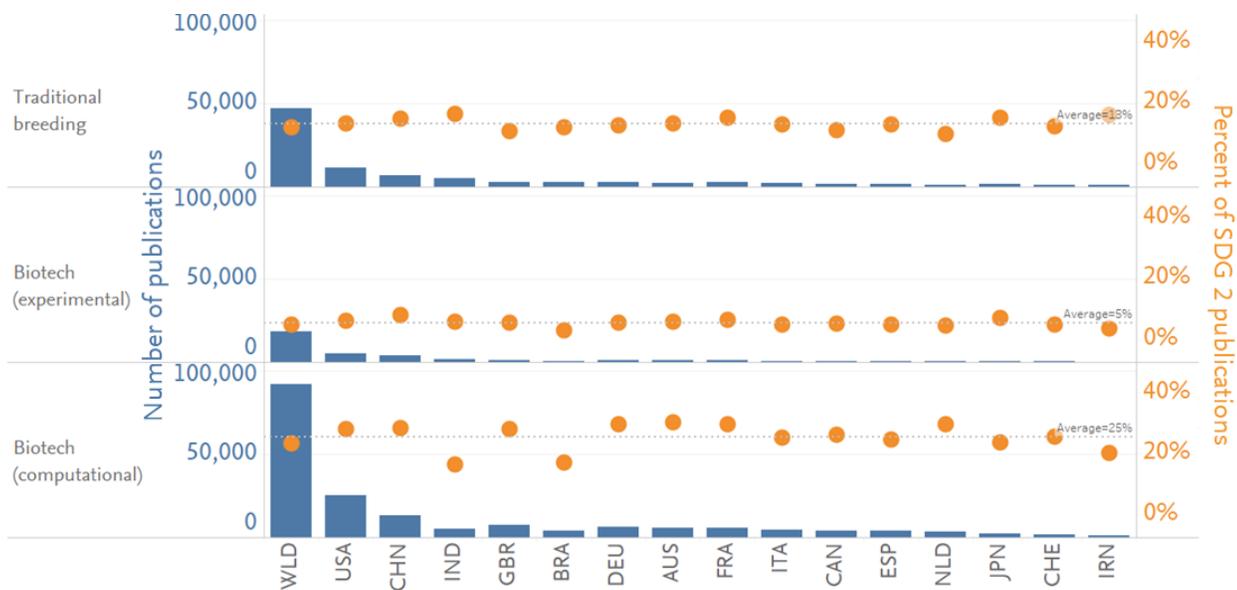


Figure 6 – Number of research publications in biotechnology subcategories of *Feeding the Planet Sustainably* research by region and percentage representation within the *Feeding the Planet Sustainably* research portfolio (2001–2020).

Source: Scopus

In general, the distribution of collaboration types within biotechnology subcategories is similar to that observed for *Feeding the Planet Sustainably* research overall, as shown in Figure 7; the academic sector contributes to the most research while the corporate sector contributes to the least. It is notable that within the traditional breeding and experimental biotechnology subcategories, less of the research is done solely by the academic sector and a greater share of the research is a result of academic-government collaboration and academic-government-NGO collaboration.

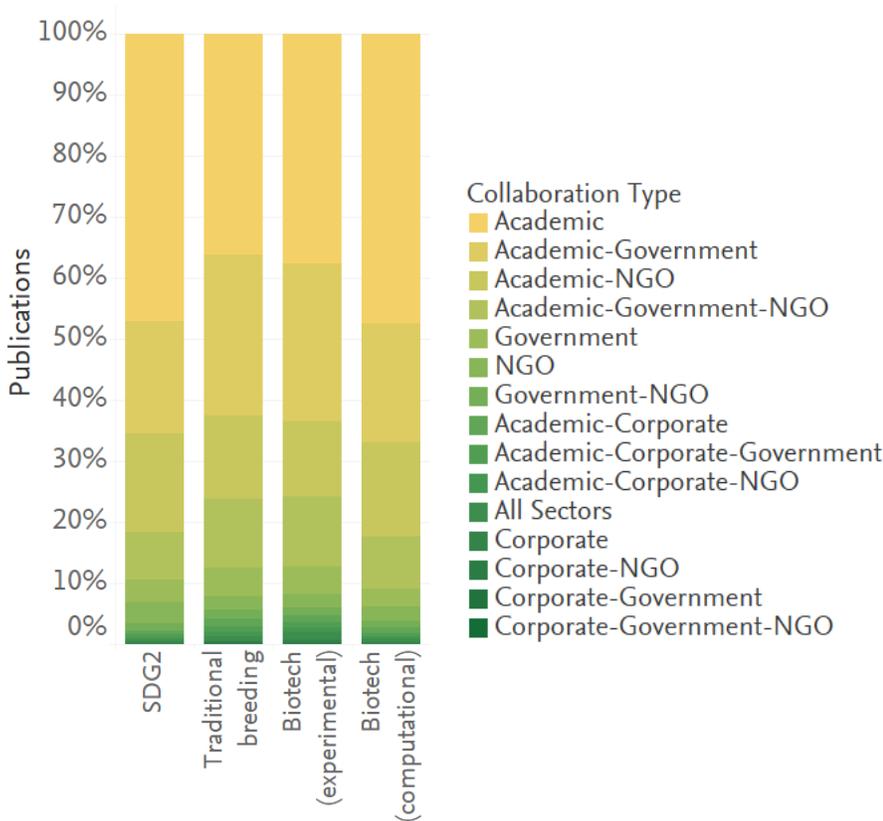


Figure 7 – Feeding the Planet Sustainably (SDG2) and biotechnology subcategory research publications from 2016–2020 categorized according to the sectors represented in the author byline.

Source: Scopus

Research uptake into other research and innovations is indicated by metrics such as citations in research publications and patents. Figure 8 shows that 2.5% to 3.5% of publications in traditional breeding and experimental biotechnology are cited in patents, while less than 1.0% of publications in computational biotechnology is cited in patents. The biotechnology subcategories have a field-weighted citation impact that is 1.2–1.4 times more than the global average, indicating the research is highly cited and has a high uptake in other research.

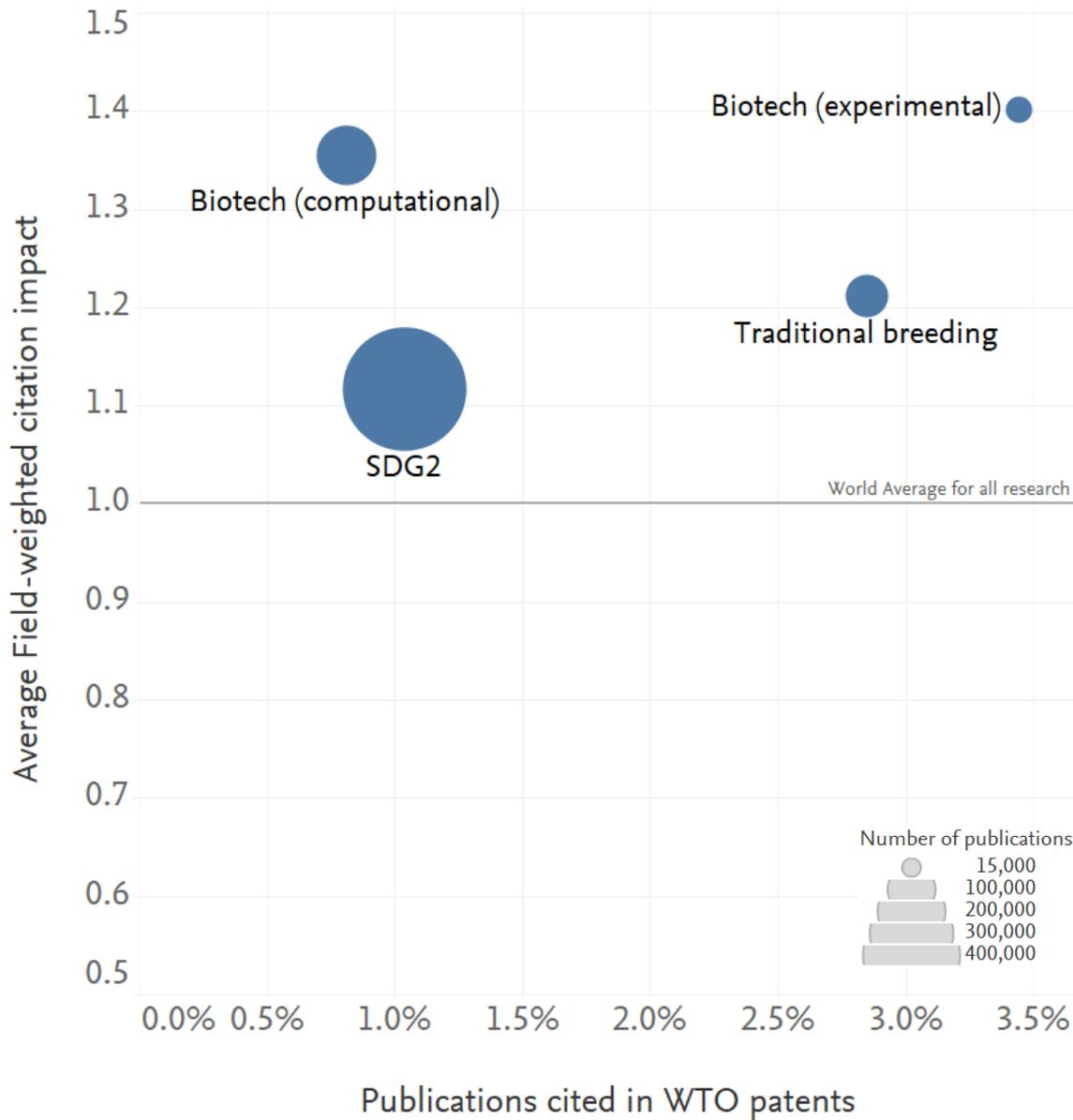


Figure 8 – Average field-weighted citation impact and percent of research cited in World Trade Organization patents for publications from 2001 –2020 in each subcategory of Feeding the Planet Sustainably (SDG2) research.  
Source: Scopus

	<b>Traditional Breeding</b>	<b>Biotech (Experimental)</b>	<b>Biotech (Computational)</b>
1	Cornell University (991)	Cornell University (451)	University of Florida (978)
2	University of Minnesota Twin Cities (639)	University of Minnesota Twin Cities (265)	Cornell University (901)
3	University of Wisconsin-Madison (451)	University of Wisconsin-Madison (185)	University of Minnesota Twin Cities (773)
4	University of Florida (426)	University of Florida (177)	Harvard University (709)
5	Ohio State University (303)	Ohio State University (136)	University of Wisconsin-Madison (668)
6	Pennsylvania State University (220)	University of California at Berkeley (100)	Ohio State University (526)
7	University of California at Berkeley (150)	Pennsylvania State University (87)	University of California at Berkeley (518)
8	Harvard University (107)	Harvard University (74)	Pennsylvania State University (489)
9	National Institutes of Health (84)	Stanford University (53)	Johns Hopkins University (449)
10	Duke University (68)	National Institutes of Health (52)	Columbia University (439)
11	University of Washington (66)	University of Washington (48)	University of Washington (397)
12	Stanford University (58)	University of California at Los Angeles (43)	Stanford University (357)
13	University of California at Los Angeles (52)	Massachusetts Institute of Technology (43)	University of Michigan, Ann Arbor (350)
14	Johns Hopkins University (49)	Duke University (32)	University of California at Los Angeles (327)
15	The University of Chicago (48)	University of California at San Diego (31)	Duke University (256)
16	University of California at San Diego (42)	The University of Chicago (29)	The University of Chicago (185)
17	University of Michigan, Ann Arbor (38)	Johns Hopkins University (28)	Massachusetts Institute of Technology (182)
18	University of Pennsylvania (35)	University of Michigan, Ann Arbor (23)	University of Pennsylvania (169)
19	Massachusetts Institute of Technology (33)	Columbia University (21)	National Institutes of Health (153)
20	Columbia University (30)	University of Pennsylvania (17)	University of California at San Diego (140)

Table 4 – Top 20 institutions publishing research within each subcategory of *Feeding the Planet Sustainably* research, ranked by publication output during the period 2001–2020, indicated in parentheses.

Source: Scopus

## Conclusions

Research focused on the goal of *Feeding the Planet Sustainably* spans several concepts, including food security, malnutrition, and increasing crop yields. Over the past two decades, nearly 400,000 research publications have been published that focus on this goal. Between 2001 and 2020, global research output focused on *Feeding the Planet Sustainably* grew at a compound annual growth rate of 9.6%, outpacing the compound annual growth rate of overall global research output by four percentage points. While the United States published the most research towards the goal of *Feeding the Planet Sustainably*, many of the top countries publishing in this area dedicated more of their research portfolio to the topic, with Brazil allocating the greatest national share (2.4% of the country's research portfolio). Among the various sectors that conducted research in this area, academic institutions contributed the most, and are represented among authors in approximately 90% of the publications.

Globally, biotechnology research is highly represented within the corpus of research on *Feeding the Planet Sustainably*, with computational biotechnology research representing 23%, traditional breeding research representing 12%, and experimental biotechnology research representing 5% of the research published in the past two decades. Traditional breeding research and experimental biotechnology research maintained their shares of the *Feeding the Planet Sustainably* research over time. In contrast, computational biotechnology research increased representation within research focused on *Feeding the Planet Sustainably* by 12 percentage points, from 15% of the total research in 2001 to 27% of the total research in 2020. Overall, biotechnology research stands apart from other research focused on *Feeding the Planet Sustainably* because a smaller share of biotechnology research was conducted solely by the academic sector and a greater share of this research was conducted through academic-government collaborations. In terms of citation impact, all biotechnology research has been cited 1.2 to 1.4 times more than the global average. Additionally, both traditional breeding research and experimental biotechnology research have been cited more commonly in patents, with 2.5% to 3.5% of the research in these subcategories having been cited in patents compared to approximately 1.0% of research that has been cited in patents for both computational biotechnology research and for *Feeding the Planet Sustainably* research overall. Together, these findings show the integral role that biotechnology research plays toward *Feeding the Planet Sustainably*.



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