

Science-Metrix

**Science quality and research
impact study – Advisory Service
on Agricultural Research for
Development (BEAF)**
Final synthesis report



Science quality and research impact study – Advisory Service on Agricultural Research for Development (BEAF) Final synthesis report

Date:

December 15, 2020

Study Team:

Henrique Pinheiro
David Campbell
Etienne Vignola-Gagné
Jörg Hellwig

Submitted to:

Deutsche Gesellschaft für Internationale
Zusammenarbeit (GIZ) GmbH

By:



Science-Metrix Inc.

1335 Mont-Royal E. ■ Montréal ■ Québec ■ Canada ■ H2J 1Y6

1.514.495.6505 ■ 1.800.994.4761

info@science-metrix.com ■ www.science-metrix.com



Executive summary

In this study, Science-Metrix was mandated by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH to perform a bibliometric assessment of roughly 130 projects funded by the Advisory Service on Agricultural Research for Development (BEAF). These projects were awarded between 2001 and 2019 across 17 international agricultural research centres (IARCs). The study specifically aimed (1) to assess the quality and impact/influence of BEAF-supported publications within academic circles (e.g., Are the research outputs being further developed/adapted by peers or the original authors of the studies?); (2) to uncover the thematic content of the produced outputs in relation to the United Nations' Sustainable Development Goals (SDGs); and (3) to investigate the cost-efficiency with which BEAF-supported publications were produced.

Overall, close to 900 peer-reviewed publications produced by BEAF-supported projects and indexed in Scopus (Elsevier's abstract and citation database of peer-reviewed literature) were used in producing this assessment. A data set of publications on agricultural research for development was created to capture information on leading research organizations in the thematic space of greatest relevance to BEAF. For example, this data set was used to identify the 15 most publishing research institutions in agricultural research for development as well as to circumscribe the relevant publications of an additional 15 institutions identified by GIZ staff as sharing similar priorities to BEAF. Other publications by the IARCs, not funded by BEAF, were also used as a comparator. For the cost-effectiveness analysis, research projects funded by the European Commission's Framework Programmes for Research and Technological Development (FP7 and H2020) were used to contextualize BEAF's figures more so than to offer a robust benchmark. Below is a summary of the study's key findings:

- The BEAF lead in terms of scientific impact was nearly systematic across the selected indicators and most of the comparator groups. The below sub-findings together illustrate the strong influence of the research supported by BEAF, at least as measured through citation-based indicators.
 - BEAF scientific impact was generally consistent with the aggregate figure for the group of 15 institutions of similar priority.
 - BEAF's performance in impact was notable when publications produced by the IARCs but not supported by BEAF were used as reference.
 - BEAF impact was higher than that of research in the same topics of prominence.
- The BEAF degree of international collaboration stood out from that of most of the comparators, except for the other IARC publications, which scored similarly. One compelling factor to explain such performance could be that BEAF research takes advantage of the existing IARC networks, which would result in both groups scoring similarly and above the comparators for this dimension.
- BEAF publications scored above world level and similarly to all comparator groups for share of open access (OA) publications.
- The content analysis revealed that BEAF and the IARCs are more aligned to the content of the SDGs compared with the top institutions and the institutions of similar priority.
- The cost-effectiveness indicators presented in this report suggest that BEAF-supported projects may be outperforming other projects with similar scope. However, extra caution is advised in interpreting these results.

Contents

Executive summary.....	i
Contents	ii
Tables.....	ii
Acronyms.....	iii
1 Introduction	1
1.1 Context	1
1.2 Research questions.....	2
2 Results	3
2.1 Scientific impact.....	3
2.1.1 BEAF and comparators	3
2.1.2 Disaggregation of BEAF-funded research	6
2.2 Collaboration and open access	10
2.3 Content analysis	12
2.4 Cost-effectiveness of BEAF research	14
3 Conclusions	18
Appendix—Methods.....	19

Tables

Table I	Scientific impact of BEAF-supported publications and the selected groups of comparators (2001–2019).....	5
Table II	Scientific impact of the most impactful institutions of similar priority (2001–2019)	6
Table III	Scientific impact of BEAF-supported publications and other IARC publications (2001–2019).....	7
Table IV	Scientific impact of BEAF-supported publications by region (2001–2019)	8
Table V	Scientific collaboration of BEAF-supported publications and groups of comparators by region (2001–2019).....	11
Table VI	Scientific collaboration of BEAF-supported publications and other IARC publications (2001–2019).....	12
Table VII	Scientific impact of BEAF-supported publications by the three main topics of prominence (2001–2019).....	13
Table VIII	Volume of output and specialization index of BEAF-supported publications and its comparators by SDG (2001–2019)	14
Table IX	Cost-effectiveness of BEAF-supported publications (2001–2019)	17
Table X	Decile weighting to compute citation distribution index	26

Acronyms

ANA	Average number of authors
ANC	Average number of countries
ARC	Average of relative citations
AVRDC	World Vegetable Center
BEAF	Advisory Service on Agricultural Research for Development
CDC	Citation distribution chart
CDI	Citation distribution index
CGIAR	Consultative Group on International Agricultural Research
CIFOR	Center for International Forestry Research
CIMMYT	International Maize and Wheat Improvement Center
FWCS	Field-Weighted CiteScore
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HCP	Highly cited publications
IARC	International agricultural research centre
ICARDA	International Center for Agricultural Research in the Dry Areas
ICIPE	International Centre of Insect Physiology and Ecology
ICR	International collaboration rate
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
OA	Open access
PPP	Public–private partnerships
RC	Relative citation
SDGs	Sustainable Development Goals
SI	Specialization index

1 Introduction

1.1 Context

Within the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the Advisory Service on Agricultural Research for Development (BEAF) supports 17 international agricultural research centres (IARCs)¹ aiming to develop/deploy innovative solutions for sustainable agriculture in developing countries. Support is provided on a competitive basis through project grants (EUR 1.2 million for 3 years per project). Eight to nine new projects are funded each year. They vary in their objectives, thematic scope/methods, targeted countries and research stage (discovery, proof of concept, piloting, scaling).

Once a project is completed, the research team submits a final research report detailing its key research (e.g., publications) and development (methods, tutorial videos) outputs. These reports then help BEAF evaluate its funded projects. Because an assessment of these projects' longer-term outcomes (e.g., increased yields of smallholders) is typically not possible right after projects are completed, BEAF commissions additional retrospective evaluations. One such evaluation was performed in 2016/17 to look at roughly 100 projects across the 17 IARCs. The study concluded that most projects were in early stages of the research-for-development pathway (e.g., discovery). In other words, their results mostly consisted of research outputs to be further developed/adapted (within academic circles) and taken up/implemented (in broader circles—for example, by partners, stakeholders and beneficiaries).

Apart from the mid- and longer-term development impacts the 2016/17 assessment was aiming to track, the study's conclusion uncovered an additional area of high relevance to the assessment of BEAF's financial support to the IARCs. This additional area is the assessment of (1) the quality and impact/influence of BEAF-supported publications within academic circles (e.g., Are the research outputs being further developed/adapted by peers or the original authors of the studies?); (2) the cost-efficiency with which BEAF-supported publications were produced; and (3) the thematic content of the outputs produced. This complementary impact assessment should cover roughly 130 projects awarded to the 17 IARCs from 2001 to 2019, which resulted in close to 1,500 research outputs (e.g., peer-reviewed publications, conference presentations, abstracts). To achieve this, BEAF/GIZ contracted Science-Metrix (part of Elsevier), which is specialized in research evaluation using bibliometric methods.

This report provides a portrait of the BEAF-supported scientific publications regarding their impact within the academic community, degree of open access (OA), collaboration and thematic content. This portrait covers points 1 and 3 above. A data set of scientific publications on agricultural research for development was collated to provide a world-level comparator in the research area most relevant to BEAF-supported research. Within this data set, the 15 most publishing research institutions were identified to serve as institutional comparators. GIZ staff identified an additional 15 institutions prominent in agricultural research for development, and these were added to the comparators.

To produce this portrait, BEAF's scientific performance was disaggregated by IARC, region, country, research topic and thematic relevance toward the United Nations Sustainable Development Goals

¹ Fifteen of which are part of the Consultative Group on International Agricultural Research (CGIAR).

(SDGs). This finer-grained analysis of BEAF-supported output is intended to uncover how scientific performance has been distributed across key dimensions of interest to GIZ. The disaggregation of BEAF-supported publications by IARC is accompanied by a comparison to other IARC publications (i.e., those not funded by BEAF) as a proxy for the performance of BEAF relative to other funding sources; this assumes BEAF distributed its funding to the IARCs in a similar way to other funding sources (e.g., similar distribution, on a competitive basis, of funding across region, topic).

Finally, this report also presents figures on the cost-effectiveness of BEAF research (point 2 above). Results for a list of research projects funded by the European Commission's Framework Programmes for Research and Technological Development (FP7 and H2020) are also provided to put them in perspective rather than to offer a robust benchmark.

1.2 Research questions

The scope of this report was delineated in earlier stages of this project, more specifically through the Statement of Work, the inception report and other interactions with the GIZ team. This report focuses on analyzing the bibliometric scores of BEAF-supported publications, using a comparative strategy to provide evidence to answer the following research questions covering four dimensions.

Scientific impact

- **Q1:** What is the overall scientific impact of the funded research projects and their peer-reviewed publications on peer researchers?
- **Q2:** What is their relative scientific impact compared to publications from selected leading research institutions in the same research domains?
- **Q3:** What type of publications and research projects (for example, disaggregated along subject areas, IARCs, regional foci, methods) are particularly impactful?

Scientific collaboration and open access

Q4: What is the extent of institutional and cross-sector collaboration among BEAF-funded publications (overall and by subgroup of BEAF-supported papers)?

- **Q5:** What is the share of OA publications compared to those from selected comparators? Which categories of BEAF projects stand out in this respect? Do OA (total, gold and green) papers have a citation advantage in BEAF's context?

Thematic content

- **Q6:** To what extent are cross-cutting issues such as gender, human rights, sustainability, resilience, and climate change mitigation and adaptation addressed in the peer-reviewed publications?

Efficiency

Q7: How are the research outputs and impacts to be evaluated in relation to the monetary inputs? How cost-efficient are the research activities compared to other research institutions?

Prior diving into the results section, note that a comprehensive description of the methods (including indicator definitions) is available in appendix.

2 Results

This section addresses most of the research questions motivating this report. The average of relative citations (ARC), Field-Weighted CiteScore (FWCS), highly cited publications (HCP) (1% and 10%), citation distribution index (CDI) and citation distribution chart (CDC) are presented and discussed on a comparative basis (BEAF and comparators) to depict the scientific impact of BEAF-supported scientific publications (Q1, Q2 and Q3) in Section 2.1. The international collaboration rate (ICR), average number of countries (ANC), average number of authors (ANA), and the share of public–private co-publications (PPP) are used to depict the scientific collaboration patterns of BEAF-supported research relative to its comparators (Q4). The share of OA publications is used to address question Q5, providing an appraisal of BEAF’s performance in providing accessible scientific content to the scientific community. The collaboration and OA dimensions are discussed together in Section 2.2. Question Q6 on the topical characterization of BEAF research is addressed in Section 2.3 by looking at the distribution of BEAF-supported publications and those of the comparators across the SDGs and the Scopus topics of prominence. Section 2.4 reports the cost-efficiency of BEAF research.

2.1 Scientific impact

This section describes the indicators selected to answer two main questions motivating this report, Q1 and Q2, and to partially answer Q3, which is also partly addressed in Section 2.3. The results are assessed based on two different but complementary criteria: absolute size effect² and statistical significance.³

2.1.1 BEAF and comparators

Table I presents the indicators of scientific impact of the BEAF-supported publications and the groups of selected comparators. In the upper section of this table, indicators are presented for all BEAF-supported publications and for other IARC publications, irrespective of thematic focus. In the lower part of the table, only those publications intersecting the thematic data set are represented, allowing for the computation of indicators for the group of top institutions on agricultural research for development as well as for the institutions of similar priority. To maximize the comparability of BEAF-supported publications (and those of other IARC publications) to these comparators, the scores for BEAF (and the IARCs) were also computed for their publications intersecting with the thematic data set.

BEAF-supported publications, from an overall point of view, outperformed those of the comparators. When all publications were considered, those supported by BEAF outperformed other papers published by the IARCs on most of the presented indicators. This performance seems to be consistent across

² Internal guiding parameters for minimal differences on impact indicators that matter in practice are as follows: ARC and FWCS, 0.1; HCP_{10%} and HCP_{1%}, 0.25; CDI, 2.5. Such thresholds are partly subjective and open to reconsideration depending on the client’s context. We thus recommend retaining flexibility in using such thresholds.

³ For this project, the p -values presented refer to two-tailed tests for the difference of means between BEAF and comparators. They are presented in the form of symbols (** $p < 0.01$, * $p < 0.05$, † $p < 0.1$). In some cases (e.g., some IARCs in Table III) the statistical power may be low due to the low number of publications in some groups. Therefore, the p -values reported in this project should be used to support the overall picture provided by each table where the indicators can be assessed together.

various impact indicators except for the HCP_{1%}, in which the performance of the two groups of publications was very close.

Indicators of impact presented in this report were normalized using the world-level scores of the same subfield (relying on a journal-based classification of science),⁴ publication year and document type as the given paper. Accordingly, the world level is set to 1 for all indicators except for the CDI (world = 0). The scores measured for the thematic data set as a whole (third row in Table I) reveal that the area of agricultural research for development contains publications that generally outperformed overall research in their corresponding subfield. For instance, the ARC of 1.11 indicates that, on average, the subset of agricultural research for development scores 11% higher than the subfields in which its publications are classified. This pattern should be accounted for in analyzing BEAF's scientific performance. Indeed, since the thematic data set is closer in scope to the BEAF research than the journal-based classification used in normalizing the papers' impact scores for the entire Scopus database, the scores for the former (e.g., ARC = 1.11) are a better benchmark than the world levels (ARC = 1.00) per the normalized indicators.

When the publications were restricted to those in the thematic data set, BEAF-supported publications still outperformed the other IARC publications. Their respective scores, as well as the pattern of differences between them, were very close to those obtained when keeping all their publications. This suggests that the publications captured by the thematic data set in agricultural research for development provide a highly representative set of papers for both groups. The impact of BEAF-supported publications strongly outperformed those from the entirety of agricultural research for development, represented by the thematic data set, in all indicators considered. Noting that BEAF funding is awarded on a competitive basis, such performance was somewhat expected. Indeed, the thematic data set represents the world-level performance in agricultural research for development, covering research performed with competitive and non-competitive funding sources. Still, it is useful to know that BEAF-funded research consistently outperformed the world level in the field and by considerable margins (e.g., the difference between BEAF and the thematic data set in ARC is 0.65, more than six times the guiding reference of 0.1 used across this project). The lead of BEAF over the top (i.e., most publishing) institutions in the field is also remarkable, with large differences (e.g., 0.44 in ARC, 0.17 in FWCS, 0.62 in HCP_{10%}) that are statistically reliable ($\alpha = 0.01$, except for HCP_{1%}). In the case of the ARC, for example, while BEAF-supported publications are, on average, 73% more cited than the average paper in the same subfield at the world level, the top institutions are only 32% more cited than the world level.

The only group in Table I that showed scientific impact comparable to BEAF's was that of the institutions of similar priority, which were selected by GIZ as representing a distinctive group of institutions in the field. BEAF led in the CDI, but not in HCP_{1%} or FWCS. Performance were similar on the ARC and HCP_{10%}. This picture suggests that BEAF support enabled the IARCs to produce scientific papers that are similar in impact to those with similar priority. By contrast, other IARC publications performances were slightly below those of institutions of similar priority. Altogether, Table I depicts a favourable picture

⁴ Note that the publications that are part of the data set on agricultural research for development fall into a diversity of subfields, each of which also includes publications irrelevant to agricultural research for development.

of BEAF-supported publications regarding their scientific impact, indicating a positive answer to the research questions Q1 and Q2 listed in Section 1.2 above.

Table I Scientific impact of BEAF-supported publications and the selected groups of comparators (2001–2019)

Group	Papers	Scientific impact					
		ARC	FWCS	HCP _{10%}	HCP _{1%}	CDI	CDC
BEAF Publications	888	1.73	1.32	2.03	2.26	21.1	
Other IARC Publications	29,349	1.59 †	1.21 **	1.64 *	2.27	12.5 **	
Thematic Dataset	934,727	1.11 **	1.02 **	1.15 **	1.17	3.6 **	
BEAF Publications	746	1.76	1.28	2.07	2.17	21.9	
Other IARC Publications	19,980	1.51 **	1.19 *	1.69 *	2.18	13.5 **	
Institutions of Similar Priority	80,945	1.73	1.39 **	2.04	2.67	17.4 **	
Top Institutions on AgriRes	186,518	1.32 **	1.11 **	1.45 **	1.61	9.0 **	

Note: ** p<0.01,* p<0.05, † p<0.1: Two-tail test for differences of means between BEAF-supported publications and each comparator.

Source: Prepared by Science-Metrix using Scopus (Elsevier) data

Table II presents the scientific impact of some institutions of similar priority. Only the publications in agricultural research for development were considered in producing these indicators, and they should therefore provide high-performing institutional comparators that are close in scope to BEAF. Five of these institutions exhibited ARC scores of 2.00 or higher: a strong performance at the institutional level in almost all evaluation contexts. Considering that the world level in agriculture research for the study period was 1.11, the scientific impact of these institutions was at least 80% higher (2/1.11). These institutions demonstrated similar patterns of achievement on the other dimensions of impact considered. All institutions presented in Table II, even those with lower scores, outperformed the world level in agricultural research for development, demonstrating the strong performance of this group in the field and illustrating the good placement of BEAF in this group of leaders, based on the scientific impact presented in Table I.

Table II also shows that the relative position of BEAF among the institutions of similar priority is dependent on the indicator considered. BEAF would place in the same position as Agro Paris Tech in this list if the ARC was considered (9th place). Its ranking would be the same considering the HCP_{10%}. Still with scores noticeably above the world level in the thematic data set, BEAF-supported publications are less frequently observed in the most highly cited publications (HCP_{1%} of 2.17 which remains really high, 11th place) and are published in less impactful journals (FWCS of 1.28, 11th place) than those from most of the institutional comparators in Table II. Most interestingly, BEAF scores higher than any of the institutions of similar priority for the CDI, an indicator representative of the full citation distribution of entities. This is due to the CDI being immune to the effect of outliers. It shows that BEAF-supported publications' scientific impact was not strictly dependent on few highly impactful papers that could have considerably pulled the ARC upward, which is usually highlighted by very high HCP_{10%} and/or HCP_{1%} score.

Table II Scientific impact of the most impactful institutions of similar priority (2001–2019)

Group	Papers	Scientific impact					
		ARC	FWCS	HCP _{10%}	HCP _{1%}	CDI	CDC
BEAF publications 2001-2019	746	1.76	1.28	2.07	2.17	21.9	
Institutions of Similar Priority	80,945	1.73	1.39	2.04	2.67	17.4	
Cornell University	7,102	2.16	1.49	2.57	4.22	20.8	
Michigan State University	5,620	2.05	1.45	2.52	4.24	19.8	
ETH Zürich	3,238	2.00	1.60	2.44	3.56	21.7	
Wageningen University and Research Centre	11,779	2.00	1.50	2.42	4.07	21.2	
University of Göttingen	3,412	2.00	1.44	2.47	3.66	19.5	
University of California, Davis	8,734	1.96	1.51	2.25	3.72	19.5	
University of Bonn	2,605	1.88	1.41	2.11	3.61	17.4	
INRAE - French National Research Institute for Agriculture, Food and Environment	18,671	1.78	1.48	2.10	2.68	19.0	
Agro ParisTech	2,577	1.76	1.60	2.00	2.59	19.1	
Swedish University of Agricultural Sciences	6,051	1.70	1.46	1.98	2.45	18.5	
Natural Resources Institute at the University of Greenwich	520	1.59	1.22	1.70	1.73	13.9	
Universität Hohenheim	3,326	1.56	1.26	1.74	1.65	16.0	
Thünen Institute	737	1.49	1.33	1.68	1.93	10.3	
China Agricultural University	10,472	1.45	1.13	1.64	1.96	11.1	
French Agricultural Research Centre for International Cooperation	5,511	1.36	1.31	1.43	1.41	12.5	

Source: Prepared by Science-Metrix using Scopus (Elsevier) data

2.1.2 Disaggregation of BEAF-funded research

Another strategy for benchmarking the impact of BEAF funding is to compare the BEAF-supported publications of an IARC against its non-BEAF-supported publications, and this for each IARC. Table I compared the aggregate figures of BEAF-supported publications and other IARC publications, showing that the lead measured was relevant from a practical point of view, as well as associated with *p*-values falling within the usual statistical significance levels. Table III below disaggregates these differences by IARC, helping to highlight those instances where BEAF-supported publications led the IARC publications funded through other sources. In performing these comparisons, we acknowledge that observed differences could be due to multiple factors which could not be tested here (e.g., Is funding attributed on a competitive basis across all funding sources supporting the IARCs? Is there a difference in the composition of awarded research teams?).

Citation impact scores could be calculated for only 10 out of the 17 IARCs,⁵ and the FWCS could be calculated for only 12 IARCs. To avoid dubious results, these indicators were only computed for groups of at least 30 publications with a valid score. For citation impact indicators, recent publications (in this case, those from 2018 and 2019) do not have an RC score since they have not had sufficient time to accumulate indicative citations. As a result, some groups of publications in Table III may not have impact scores computed even though they include 30 or more publications.

⁵ Indicators based on the citations received by papers could not be computed for the centres with fewer than 30 papers published between 2001 and 2017 (Africa Rice, Biodiversity International, CIFOR – Forestry Research, CIP – International Potato Center, ICARDA – Research in the Dry Areas, IFPRI – Food Policy, and WorldFish). Note that the CIP and ICARDA have more than 30 publications but some of them were published in 2018 or 2019.

In 8 of the 12 IARCs with a valid score, the FWCS for BEAF-supported publications exceeded that for the other IARC publications, with comparisons for 7 of them showing differences that could be considered statistically significant ($\alpha = 0.05$). Their performance confirms the finding from Table I, based on the aggregate figures, by showing that the lead of BEAF-supported publications in scientific impact seems to have been reproduced in most of the IARCs.

Scores for the International Rice Research Institute (IRRI) show the most distinct difference between the impact of BEAF-supported research and the impact of the other IARC publications. This feature is observed across all indicators presented in Table III. Although the IRRI performance excluding BEAF was already impressive when contrasted against the most impactful institutions from Table II, the BEAF-IRRI scores are much higher on all impact indicators. As an anecdotal example of the strong influence of the BEAF-supported research performed in this centre, one of the IRRI papers funded by BEAF was published in *Nature* in 2006 and had 904 citations indexed in Scopus at the time of writing the present report.⁶ This is the most impactful paper among those supported by BEAF, and the IRRI contributed to 9 of the top 30 most impactful BEAF-supported papers. To a lesser extent, the leverage in impact gained by the IARCs on the BEAF-supported publications was also notable for the International Institute of Tropical Agriculture (IITA) and the International Maize and Wheat Improvement Center (CIMMYT).

Table III Scientific impact of BEAF-supported publications and other IARC publications (2001–2019)

Group	Papers		Scientific impact														
			ARC			FWCS			HCP _{10%}			HCP _{1%}			CDI		
	BEAF	Other	BEAF	Other	Sig	BEAF	Other	Sig	BEAF	Other	Sig	BEAF	Other	Sig	BEAF	Other	Sig
IARC (all publications)	888	29,349	1.73	1.59	†	1.32	1.21	**	2.03	1.64	*	2.26	2.27		21.1	12.5	**
Africa Rice	9	634															
AVRDC - World Vegetable	48	645	1.19	0.90	†	1.00	0.91		1.25	0.65		0.00	0.47	†	20.8	1.3	**
Bioversity International	7	1,286															
CIAT - Tropical Agriculture	62	2,189	1.67	1.80		1.27	1.28		1.84	1.80		0.00	3.26	**	24.9	14.0	**
CIFOR - Forestry Research	19	1,701															
CIMMYT - Maize and Wheat Improvement	66	3,447	2.75	1.86	*	1.38	1.20	*	3.64	2.29	*	9.09	3.04		33.0	18.7	**
CIP - International Potato Center	33	1,003				1.40	1.07	*									
ICARDA - Research in the Dry Areas	32	1,669				1.21	1.02	†									
ICIPE - Insect Physiology and Ecology	186	1,502	1.35	1.26		1.11	1.18		1.14	1.44		0.71	0.85		20.4	11.4	**
ICRAF - World Agroforestry	79	2,264	2.19	1.86	*	1.74	1.32	*	2.76	2.06		5.08	3.92		27.7	16.9	**
ICRISAT - Crops Research for the Semi-Arid	69	2,810	1.44	1.35		1.31	1.11	*	0.82	1.45	†	1.64	1.91		23.4	9.4	**
IFPRI - Food Policy	29	2,659															
IITA - Tropical Agriculture	89	2,685	2.01	1.00	**	1.14	1.03	†	2.61	0.88	**	4.41	0.88		28.8	3.3	**
ILRI - Livestock Research	89	2,706	0.92	1.55	**	1.23	1.32		0.61	1.51	**	0.00	2.32	**	6.0	11.2	
IRRI - Rice Research	75	2,821	3.39	1.95	**	1.86	1.35	**	4.35	2.32	**	6.45	3.35		38.9	19.5	**
IWMI - Water Management	32	1,907	0.54	1.42	**	0.86	1.15	**	0.00	1.45	**	0.00	1.79	**	-3.6	11.6	**
WorldFish	12	724															

Note: ** p<0.01, * p<0.05, † p<0.1: Two-tail test for differences of means between BEAF-supported publications and each comparator. “Sig cells” in light green indicate the BEAF-supported publications lead in that indicator, whereas cells in light red indicate the other IARC publications lead.

Source: Prepared by Science-Metrix using Scopus (Elsevier) data

The regional dimension of the BEAF-supported publications is depicted in Table IV and Figure 2. Table IV shows the number of publications per region (using the UN regionalization as reference), as well as

⁶ Xu, K., Xu, X., Fukao, T. et al. (2006). Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice. *Nature* 442, 705–708. <https://doi.org/10.1038/nature04920>

the usual indicators of scientific impact. Eastern Africa's lead in number of papers can be partially explained by the number of papers from the International Centre of Insect Physiology and Ecology (ICIPE) and the International Livestock Research Institute (ILRI) (Table III),⁷ which are based in this region (see Figure 1 below). It is important to keep in mind that, despite having scored below the BEAF average in impact, the research pertinent to this region is above the world level in the field for most of the indicators (e.g., the ARC in the thematic data set was 1.11).

Table IV Scientific impact of BEAF-supported publications by region (2001–2019)

Group	Papers	Scientific impact					CDC
		ARC	FWCS	HCP _{10%}	HCP _{1%}	CDI	
All BEAF-supported Publications	888	1.73	1.32	2.03	2.26	21.1	
Eastern Africa	466	1.45	1.18	1.61	0.54	18.8	
South-eastern Asia	204	2.25	1.56	3.08	4.14	28.5	
Southern Asia	163	2.46	1.47	3.25	3.01	31.4	
Western Africa	159	1.58	1.21	2.17	2.10	19.9	
South America	94	1.53	0.91	2.00	0.00	19.9	
Central America	93	2.26	1.17	3.60	3.37	25.9	
Middle Africa	77	1.77	1.23	2.38	1.45	25.7	
Western Asia	76	1.78	1.19	2.11	3.95	21.3	
Western Europe	74	1.45	1.19	2.09	0.00	16.5	
Eastern Asia	66	2.26	1.39	3.22	1.69	33.8	
Northern Africa	47	2.29	0.94	3.48	4.35	28.9	
Southern Africa	36	1.26	1.12	1.38	0.00	10.6	
Central Asia	31	N/C	N/C	N/C	N/C	N/C	
Eastern Europe	17	N/C	N/C	N/C	N/C	N/C	
Caribbean	12	N/C	N/C	N/C	N/C	N/C	
Australia and New Zealand	1	N/C	N/C	N/C	N/C	N/C	
Southern Europe	1	N/C	N/C	N/C	N/C	N/C	

Source: Prepared by Science-Metrix using Scopus (Elsevier) data

Two regions in Table IV, South-eastern Asia and Southern Asia, together host or co-host at least five CGIAR centres⁸ and the World Vegetable Center (AVRDC), helping to explain the prominence of these regions in terms of number of publications. The IRRI was the most relevant centre to the output in these regions, with 70 of their 75 papers linked to these two regions. However, the relevance of other centres that are not listed as being based in these regions in Figure 1 was also noted. The World Agroforestry Centre (ICRAF) and the CIMMYT are two of these examples, highlighting the multiregional aspect of many of these centres, which provide substantial contributions to different regions across the world. It is

⁷ The regional relevance of a paper is not always determined by the centre's location. Therefore, the number of papers per centre in each region was computed (but not presented) to certify if a centre's location was reproduced in terms of number of papers relevant to their respective regions. For instance, most of ICIPE's and ILRI's papers were pertinent to Eastern Africa, where they are located. However, the ICRAF, also located in Eastern Africa (Figure 1), had most of its publications assigned to South-eastern Asia (the link between publications and countries/regions was based on the information provided by GIZ linking publications, centres, projects and countries).

⁸ International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Water Management Institute (IWMI), International Rice Research Institute (IRRI), WorldFish, and Center for International Forestry Research (CIFOR).

also noteworthy that the research performed in these two regions scored considerably above the average BEAF level in terms of impact in all indicators, highlighting their significant contribution to the overall standing of BEAF-supported publications in terms of scientific impact.

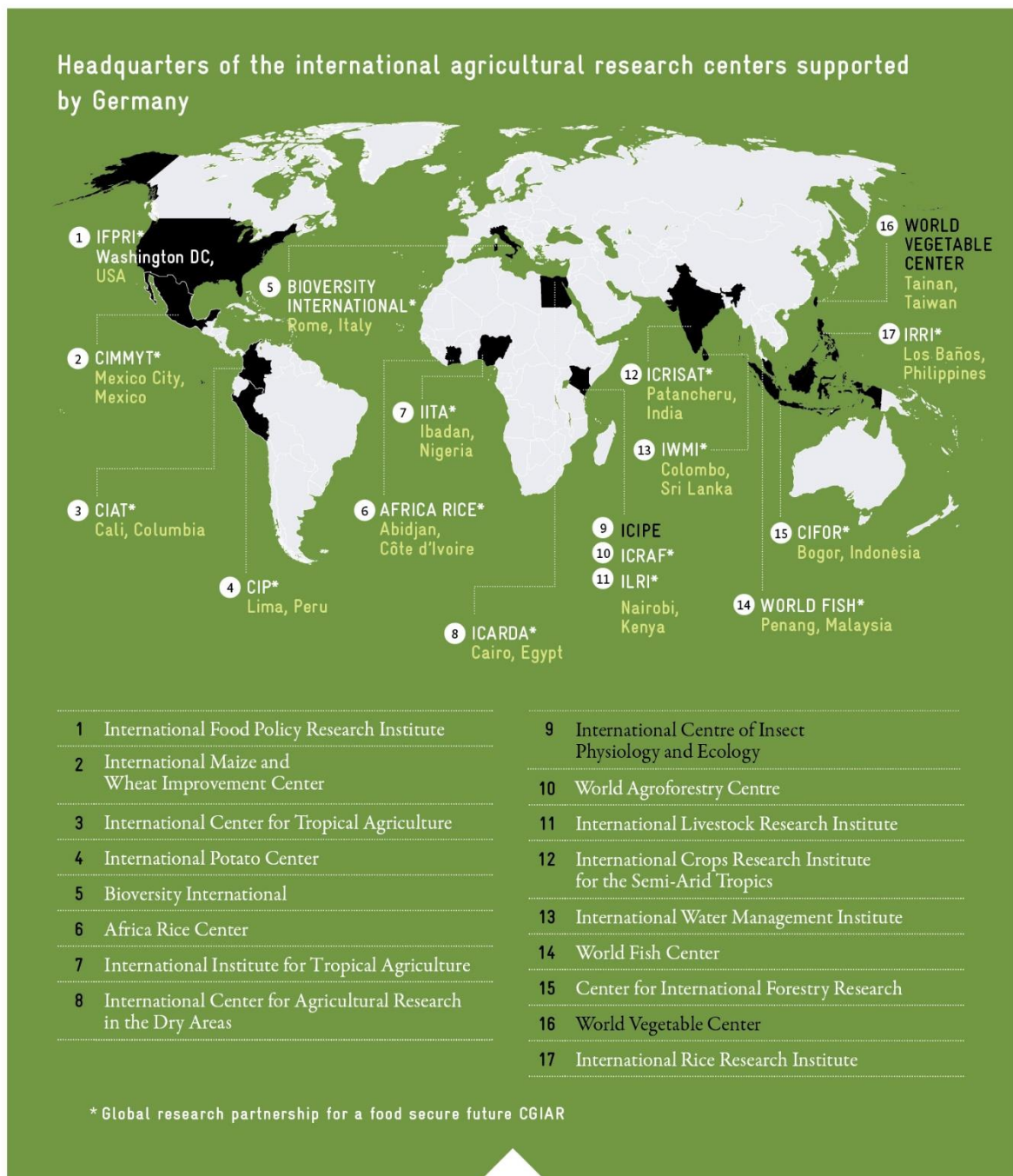


Figure 1 Headquarters of the 15 CGIAR research centres, the World Vegetable Center and ICIPE

Source: Extracted from the GIZ website (<https://www.giz.de/en/worldwide/72136.html>)

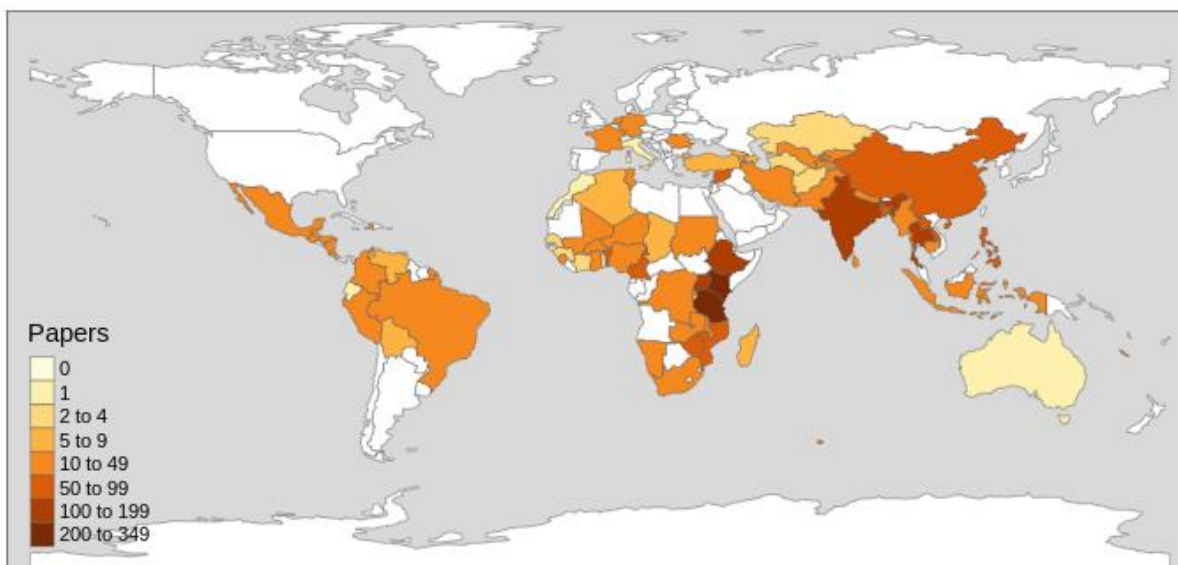


Figure 2 BEAF-supported publications by country
Source: Prepared by Science-Metrix using Scopus (Elsevier) data

2.2 Collaboration and open access

This section reports the findings pertinent to two supplemental questions motivating this project (Q4 and Q5) regarding BEAF patterns in scientific collaboration and in providing OA publications to the scientific community. Apart from being desirable from a purely scientific point of view, these dimensions have been positively associated with scientific impact⁹ and can therefore be seen as viable strategies to increase the reach of scientific publications. The tables reported in this section follow the same structure as those from the previous section and are, in some cases, presented together in the accompanying Excel databook, allowing for more comprehensive comparisons between BEAF and its comparators.

Table V provides four indicators of scientific collaboration and one representing the share of papers made available in OA. The first line of this table reveals that 79% of all BEAF-supported papers were written as co-publications between scientists from two or more countries (measured by the ICR). This research involves, on average, 2.5 countries (ANC) and 5.9 authors (ANA), with 6.3% of the papers having at least one author from a public institution (usually one university or a public research centre) and one from a private-for-profit institution (usually companies and consulting firms) (PPP). Finally, 50.8% of BEAF papers were made available in some form of OA (including gold, green and other forms of OA).

When the collaborative aspect of BEAF-funded research is contrasted against that of other IARC publications, no distinguishable pattern is observed except for a slightly lower number of authors (5.9 vs. 6.4) on BEAF-supported publications when all the publications from the two groups are considered. This

⁹ Struck, D. B., Roberge, G., & Campbell, D. (2017). The influence of open access, gender and co-authorship on citation scores. *Science, Technology & Innovation (STI) Indicators 2017*. Retrieved from <https://sti2017.paris/wp-content/uploads/2017/11/oa-db-struck-et-al.pdf>.

difference is almost non-existent when the comparison is restricted to those publications in the thematic data set, suggesting no relevant difference in collaboration among BEAF-supported publications and the other IARC publications. This pattern would appear consistent with a funding program that did not emphasize new or extra scientific collaboration from its funded teams. The comparison against other groups reveals that BEAF-funded research and the IARCs' research more generally are considerably more collaborative than the research of the most publishing institutions in the field, the research of the institutions of similar priority and the world level in the thematic data set.

The last column of Table V shows that 50.8% of all BEAF-supported publications were made available in OA, which is lower than the shares measured for the other IARC publications. The degree of OA among BEAF-supported publications is close to the averages of the top institutions in the field and those of similar priority, as well as above the world level in the thematic data set.

Table V Scientific collaboration of BEAF-supported publications and groups of comparators by region (2001–2019)

Group	Papers	Scientific collaboration				Share OA (%)
		ICR	ANC	ANA	PPP (%)	
BEAF Publications	888	0.79	2.5	5.9	6.3	50.8
Other IARC Publications	29,349	0.78	2.6 *	6.4 **	6.5	55.4 **
Thematic Dataset	934,727	0.24 **	1.3 **	4.7 **	4.9 *	43.8 **
BEAF Publications	746	0.80	2.6	6.0	6.8	50.3
Other IARC Publications	19,980	0.78	2.5	6.1	6.5	54.0 †
Institutions of Similar Priority	80,945	0.51 **	1.9 **	5.8	6.3	51.2
Top Institutions on AgriRes	186,518	0.30 **	1.5 **	5.7 *	4.7 *	48.9

Note: ** p<0.01, * p<0.05, † p<0.1: One-tail test for differences of means between BEAF-supported publications and each comparator group.

Source: Prepared by Science-Matrix using Scopus (Elsevier) data

The collaboration and OA scores disaggregated by institutions are presented in the accompanying Excel databook. The Natural Resources Institute at the University of Greenwich stood out for its higher ICR (0.80). Collaborations with African institutions in Uganda, Tanzania, Kenya and Nigeria are among the most prominent for this centre.

Table VI presents the disaggregation of BEAF-supported research and the share of its papers in OA by IARC, comparing the performance against the other publications for each centre. No clear lead was observed for either of these groups of publications at the aggregated level, and the pattern across different IARCs does not suggest a clear lead for any of these groups. Table VI reveals a low variability among IARCs for ICR and ANC, when other IARC publications are considered. For example, the ICR in Table VI ranges from 0.60 (ICRISAT) to 0.87 (ICIPE), contrasting, for example, with the range of the ICRs observed for institutions of similar priority, which span from 0.30 for the China Agricultural University to 0.80 for the Natural Resources Institute at the University of Greenwich (data in the accompanying Excel databook). This pattern can be related to the organizational structure of most IARCs under the CGIAR, which could explain the intense international collaborations in their research.

Table VI Scientific collaboration of BEAF-supported publications and other IARC publications (2001–2019)

Group	Papers		Scientific collaboration									Share OA (%)					
			ICR			ANC			ANA						PPP (%)		
	BEAF	Other	BEAF	Other	Sig	BEAF	Other	Sig	BEAF	Other	Sig	BEAF	Other	Sig	BEAF	Other	Sig
IARC (all publications)	888	29,349	0.79	0.78	†	2.5	2.6		5.9	6.4		6.3	6.5		50.8	55.4	
AVRDC - World Vegetable	48	645	0.92	0.80	**	2.9	2.6	†	6.3	5.7	†	14.6	6.7	†	43.5	46.2	
CIAT - Tropical Agriculture	62	2,189	0.95	0.83	**	3.1	3.0		7.0	6.5		12.9	8.4		66.1	56.1	†
CIMMYT - Maize and Wheat Improvement	66	3,447	0.80	0.79		3.2	2.5	*	6.7	6.7		7.6	7.9		66.7	53.8	*
CIP - International Potato Center	33	1,003	0.61	0.83		2.5	2.9		6.5	6.6		9.1	7.3		42.4	56.5	
ICARDA - Research in the Dry Areas	32	1,669	0.91	0.84	†	2.9	2.8		5.8	6.4		15.6	5.6	†	50.0	40.1	
ICIPE - Insect Physiology and Ecology	186	1,502	0.81	0.87		2.4	2.8		6.0	6.6		3.8	4.5		41.8	65.4	
ICRAF - World Agroforestry	79	2,264	0.89	0.85		3.0	3.3		6.4	7.8		5.1	7.3		55.7	52.8	
ICRISAT - Crops Research for the Semi-Arid	69	2,810	0.91	0.60	**	3.2	2.3	**	7.1	7.0		4.3	4.8		85.1	88.7	
IITA - Tropical Agriculture	89	2,685	0.93	0.82	**	3.1	2.8	†	6.4	5.7	†	7.9	13.9		49.4	48.6	
ILRI - Livestock Research	89	2,706	0.88	0.84		3.0	3.0		7.6	7.3		4.5	6.4		52.8	58.0	
IRRI - Rice Research	75	2,821	0.77	0.86		2.4	2.7		6.9	7.4		4.0	5.9		44.4	45.6	
IWMI - Water Management	32	1,907	0.69	0.78		2.2	2.6		4.6	4.8		0.0	4.9		31.3	41.1	

Note: ** p<0.01, * p<0.05, † p<0.1: One-tail test for differences of means between BEAF-supported publications and each comparator.

Source: Prepared by Science-Metrix using Scopus (Elsevier) data

2.3 Content analysis

The Scopus topics of prominence¹⁰ helped to delineate the BEAF-funded research content. Table VII lists the three main aggregations of topics of prominence for BEAF research. The disaggregated topics are listed in the accompanying Excel databook, which can help to fully appreciate the range of content within each of the three main aggregations. The aggregated level of topics of prominence does not include ready-to-use tags, but visual inspection made it possible to roughly describe Topic 339 as containing research on crop productivity, Topic 129 as dominated by research on crop diseases, and Topic 11 as grouping research on soil.

This analysis based on the topics of prominence also revealed that, at least partially, the performance of BEAF-funded research in terms of scientific impact can be related to the impact of its main topics of prominence. The impact of the thematic data set in these three topics seems to be greater than the average impact of the thematic data set for most of the indicators (i.e., the ARC, HCP_{10%} and CDI). When the main BEAF topics are taken into consideration, representing about 50% of BEAF papers (9 main topics), the ARC reaches 1.42, whereas the overall ARC for the entire thematic data set is 1.11.

Table VII suggests that the BEAF leverage in impact can be explained, at least partially, by the higher impact of the main topics of prominence for BEAF-supported publications. Table VIII also shows that BEAF-supported publications exceeded the world level in impact for Topics 339 and 11, with an unclear pattern on Topic 129 (BEAF leads in CDI but not in ARC). When the topics encompassing about half of the BEAF-supported publications are considered, these publications also show a lead in impact compared to the thematic data set. Altogether, these data show that BEAF-supported publications outperformed the world level in agricultural research for development, even after accounting for the potential effect of the higher impact of their most common topics of prominence.

¹⁰ <https://www.elsevier.com/solutions/scival/releases/topic-prominence-in-science>

Table VII Scientific impact of BEAF-supported publications by the three main topics of prominence (2001–2019)

Group		Papers	Scientific impact				
			ARC	FWCS	HCP _{10%}	HCP _{1%}	CDI
Topic 339	BEAF	98	2.50	1.45	3.52	5.00	30.9
	Thematic Dataset	12,855	1.13	0.91	1.23	1.09	4.6
Topic 129	BEAF	89	1.17	1.09	0.89	0.00	17.1
	Thematic Dataset	6,546	1.31	1.13	1.45	1.65	7.8
Topic 11	BEAF	67	2.60	1.53	2.62	6.56	30.3
	Thematic Dataset	12,397	1.66	1.31	2.01	2.48	14.1
Main BEAF	BEAF Publications	407	1.87	1.32	2.17	2.99	22.7
Topics	Thematic Dataset	49,224	1.42	1.15	1.64	1.92	10.0
All publications	BEAF Publications	888	1.73	1.32	2.03	2.26	21.1
	Thematic Dataset	934,727	1.11	1.02	1.15	1.17	3.6

Note: Only the topics with more than 30 BEAF-supported publications are presented in this report (the accompanying Excel databook lists all topics).

Source: Prepared by Science-Matrix using Scopus (Elsevier) data

The distribution of the BEAF-funded research and that of the main group of comparators across the different SDGs is presented in Table VIII. This exercise is based on an extensive effort to categorize the scientific publications in Scopus according to their relevance to each SDG. The specialization of the BEAF-supported publications is similar to that of the other IARC publications when all SDGs are taken together, with both groups exhibiting an overall SI in SDGs that is higher than the other comparator groups. With specialization index (SI) of 1.5, the share of BEAF-supported publications intersecting with the SDGs was 50% higher than at world level in the thematic data set. For other IARC publications, this figure stood at 1.4. The SDGs in which these two groups are more specialized also showed a similar pattern (No poverty; Zero hunger; Gender equality; Reduced inequalities; Climate action; and Peace, justice and strong institutions), possibly reflecting the proximity in scope between these two groups.

In absolute size (i.e., number of publications), SDG 2 (Zero hunger) was the most represented SDG for all groups considered, reflecting the relevance of agricultural research for development to this goal. The share of papers found to touch upon this SDG was 45% for BEAF (2.3 times the proportion for the thematic data set, and larger than all other comparators). BEAF-supported publications also performed well in other SDGs, such as No poverty, Gender equality, Reduced inequalities and Climate action. In these cases, BEAF-supported publications and other IARC publications alternated the lead in SI. However, since the relevance of agricultural research for development to some of the SDGs is relatively low (e.g., only 6,889 papers out of the 934,727 in the thematic data set were found to belong to SDG 10), some of these estimates are equally based on a low number of papers, suggesting caution should be exercised in the use of some of these SIs.

Table VIII Volume of output and specialization index of BEAF-supported publications and its comparators by SDG (2001–2019)

Group	Papers		1 - No poverty	2 - Zero hunger	3 - Good health and well-being	4 - Quality education	5 - Gender equality	6 - Clean water and sanitation	7 - Affordable and clean energy	8 - Decent work and economic growth
	Total	In SDGs								
BEAF publications 2001-2019	888	532	34	407	44	4	15	61	22	52
Other IARC Publications	29,349	17,301	1,547	11,564	1,437	166	508	2,540	593	2,541
Institutions of Similar Priority	80,945	35,823	796	22,700	2,367	254	168	5,147	2,355	3,856
Top Institutions on AgriRes	186,518	72,128	523	40,286	4,773	262	98	12,831	3,950	6,279
Thematic Dataset	934,727	382,692	7,644	189,341	36,142	2,724	1,872	69,359	29,129	36,633
BEAF publications 2001-2019		1.5	4.7	2.3	1.3	1.5	8.4	0.9	0.8	1.5
Other IARC Publications		1.4	6.4	1.9	1.3	1.9	8.6	1.2	0.6	2.2
Institutions of Similar Priority		1.1	1.2	1.4	0.8	1.1	1.0	0.9	0.9	1.2
Top Institutions on AgriRes		0.9	0.3	1.1	0.7	0.5	0.3	0.9	0.7	0.9
Thematic Dataset		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Group	Papers		9 - Industry, Innovation and Infrastructure	10 - Reduced inequalities	11 - Sustainable cities and communities	12 - Responsible consumption and production	13 - Climate action	14 - Life below water	15 - Life on land	16 - Peace, justice and strong institutions
	Total	In SDGs								
BEAF publications 2001-2019	888	532	20	29	7	41	103	11	75	12
Other IARC Publications	29,349	17,301	663	1,264	536	1,910	2,743	635	3,069	660
Institutions of Similar Priority	80,945	35,823	1,617	726	1,128	4,438	4,969	1,619	6,553	683
Top Institutions on AgriRes	186,518	72,128	1,975	532	2,765	6,257	8,886	3,649	14,903	381
Thematic Dataset	934,727	382,692	17,841	6,889	18,792	42,978	40,559	29,615	79,284	5,244
BEAF publications 2001-2019		1.5	1.2	4.4	0.4	1.0	2.7	0.4	1.0	2.4
Other IARC Publications		1.4	1.2	5.8	0.9	1.4	2.2	0.7	1.2	4.0
Institutions of Similar Priority		1.1	1.0	1.2	0.7	1.2	1.4	0.6	1.0	1.5
Top Institutions on AgriRes		0.9	0.6	0.4	0.7	0.7	1.1	0.6	0.9	0.4
Thematic Dataset		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Note: The data on SDG 2 were updated after the delivery of the accompanying Excel databook.

Source: Prepared by Science-Metrix using Scopus (Elsevier) data

2.4 Cost-effectiveness of BEAF research

The previous sections revealed that BEAF-supported research outperformed most of the selected comparators in terms of scientific impact and, to a lesser extent, scientific collaboration. In this latter case, the BEAF scores were roughly comparable with those from other IARC publications, but still above most comparators. In terms of OA, BEAF-supported publications scored close to those of all comparators. The research question Q7 is intended to quantify the costs associated with this achievement. Some limitations linked to the assessment of the cost-effectiveness of the BEAF scientific research are described below.

- **Differences in the proportion of BEAF publications and those from comparators that were successfully retrieved to assess cost-effectiveness**

As described in Section 0, a considerable proportion of BEAF-supported publications could be missing in the final list of publications used to support this report. This situation is far from being particular to GIZ, and we simply have no information (collecting it being beyond the scope of this project) to assess whether the recall of BEAF-supported publications is lower, higher or identical to that of the comparators used in this analysis. This uncertainty has the potential to bias the cost-effectiveness comparisons (toward or against the BEAF-supported papers). In any case, this issue is reemphasized here since it may be the most relevant threat to the results for this dimension.

- **Lack of information about co-funding**

The information provided by GIZ takes into consideration the funding amount provided by BEAF to the IARCs' research projects. However, it is possible that other contributors have also supported some of the resulting papers, meaning that part of the funds may not be considered in the computation of cost-effectiveness. This means that we will not capture the “true” or “full” cost associated with the outputs (e.g., publications and citations to these publications) BEAF contributed to, and the same applies to the comparators. Instead, we will get a sense of the output volume that BEAF contributed to for a given investment. The more a funder spreads its funding in small amounts awarded to many projects and/or attracts matching funds from other sources—actually contributing only a small share of the overall project funding—the better it should perform on this study's cost-effectiveness indicators.

- **Intrinsic differences in cost of research across fields of science**

The research costs across different projects should vary according to the nature of the type of research. For example, a research project in genetics may be more costly than another project in a more traditional topic in agriculture. Also, some research projects are more oriented to produce scientific publications, whereas others could prioritize other societal outcomes that are not always reflected in scientific publications (e.g., technical assistance). This variable is virtually impossible to control for and should be taken into consideration in the appreciation of the following results.

With the above-listed limitations to be taken into account, Table IX reports the three indicators of cost-effectiveness (publications per million euro, relative citations per million euro, and highly cited publications per million euro) for the group of BEAF-supported publications and the groups of research projects funded by the European Commission, which should be seen as references rather than matched comparator groups. The publications for the projects funded by the European Commission were extracted from the OpenAIRE platform.¹¹ This list of publications was matched to Scopus based on DOIs and on an automated algorithm that compared the similarity between the titles from the publications in the OpenAIRE list and those in Scopus. Recall (97%) and precision (> 99%) rates could only be estimated based on the list of publications extracted from OpenAIRE. Therefore, if the OpenAIRE list had missed a relevant proportion of the funded publications, the real recall rate could be considerably lower. Nevertheless, the degree of completeness of OpenAIRE is expected to be at least satisfactory for the projects funded by the European Commission, since OpenAIRE resulted from a project that received funding from the Commission and the platform is used by them to, for example, support the implementation of OA policies.¹²

The projects from the European Commission are grouped into two sets, as presented in Table IX. Group 1 contains projects having at least 50% of their publications falling into the thematic data set on agricultural research for development, whereas Group 2 contains all projects having at least one paper in this data set. Given the limitations highlighted before, this approach makes it possible to assess the

¹¹ <https://www.openaire.eu/open-science-europe-overview>

¹² Data from other funders were retrieved from OpenAire and tested for this cost-effectiveness analysis, but because we were less certain regarding their coverage, we opted for retaining only the European Commission projects.

stability of the indicators when different criteria are adopted. Each group of projects is then disaggregated according to the projects' starting years, funding amounts, and the presence of keywords in the projects' objectives linking them to agriculture, Africa or Asia.

The lines highlighted in grey contain the groups of projects that are more aligned to the BEAF scope and regional focus. The line "Objective referring to Africa", in Group 1, includes all projects that have at least 50% of their research output in the thematic data set, with funding amounts between EUR 600,000 and EUR 4.8 million, and whose objectives mentioned the word "Africa" or any African country. The same criteria were used to form the group "Asian countries in objectives", except that only the names of countries from Southern Asia and South-eastern Asia were used as geographical criteria (possibly closer to the geographical scope of the projects in the BEAF group). This stricter selection criterion resulted in only seven projects falling into this group, reducing its reliability. In Group 2, a similar subgroup is presented in the line "& objective referring to Africa", with the difference that only objectives containing "Agric" were included (for Group 1, this filter was not necessary since it only included projects with at least 50% of their papers in agricultural research for development). Group 2 outperformed Group 1 in the indicators of cost-effectiveness, suggesting that the topic of agricultural research for development is likely to generate fewer scientific outputs per funding unit than projects that—even though they have at least one paper in agricultural research for development—are less aligned to this thematic area. Even when the projects were filtered based on the presence of "Agric" in their objectives, the Group 2 projects were higher in cost-effectiveness, suggesting that the thematic area of agricultural research for development may be less cost-effective than the overall agricultural research (this analysis, however, could not account for non-scientific outputs such as technical assistance, for example).

BEAF supported, on average, 5.7 publications (indexed in the Scopus database) per million euro, which is more than the groups containing Africa-related projects in Group 1 (2.5 publications per million euro). It is also more than most subgroups in Group 1 (except for projects receiving less than EUR 600,000). When the indicator of highly cited papers per million euro was considered, BEAF still outperformed most of the subgroups of projects in Group 1, producing 1.2 highly cited papers per million euro (against 0.8 papers from Africa-related projects). The indicator of relative citations per million euro has a less intuitive meaning, since it is based on the normalized citation score (and not on the raw number of citations). Nevertheless, its comparison against the entities in Group 1 confirmed the trends observed for number of papers and highly cited papers per million euro.

The comparisons of BEAF-supported projects with the Group 2 projects invert the picture described above. As mentioned, the comparisons between the indicators for Groups 1 and 2 in Table IX may be an indication that the area of agricultural research for development is less cost-effective than the broader agricultural research encompassed in Group 2 (when only scientific outputs are considered). Perhaps the most important conclusion from this section is that although the computed indicators of cost-effectiveness suggest that BEAF-supported projects were more cost-effective than the closest comparators (under Group 1), the magnitude of the observed differences cannot reliably be computed given the aforementioned limitations in computing cost-effectiveness. For these reasons, we must re-emphasize the importance of interpreting the results from Table IX with extra caution; they may indeed be biased due to these limitations.

Table IX Cost-effectiveness of BEAF-supported publications (2001–2019)

Group	No. of projects	Share of papers in agric research	Amount funded in million euro	Million euro per project	Average starting year	Average ending year	No. of papers	Papers million euro	ARC	Relative citation per million euro	HCP _{10k}	HCP _{10k} per million euro
BEAF publications 2001-2019	128	84%	156	1.22	2009.3	2012.6	888	5.7	1.73	9.8	2.03	1.2
2008 and before	56	86%	68	1.21	2004.8	2008.3	426	6.3	1.69	10.6	1.96	1.2
2009-2012	33	86%	42	1.26	2010.5	2013.8	273	6.5	1.79	11.7	2.17	1.4
2013-2016	33	76%	40	1.22	2014.9	2017.7	197	4.9	1.79	8.7	2.17	1.1
2016-2020	5	67%	5	1.00	2017.0	2019.6	10	2.0				
Group 1: Research projects funded by the European Commission (FP7 and H2020) with at least 50% of papers in Agricultural Research for Development												
Total	791	78%	1,710	2.16	2013.4	2016.5	5,368	3.1	2.23	7.0	2.90	0.9
Funding amount < 600 K	342	80%	69	0.20	2013.1	2015.6	953	13.8	2.21	30.6	2.96	4.1
Between 600 K and 2.4 M	189	78%	305	1.61	2013.4	2016.9	1,155	3.8	1.90	7.2	2.45	0.9
Between 2.4 M and 4.8 M	146	73%	492	3.37	2012.7	2016.4	1,586	3.2	2.43	7.8	3.19	1.0
> 4.8 M	114	74%	844	7.40	2015.0	2019.0	1,855	2.2	2.28	5.0	2.91	0.6
Between 600 k - 4.8 M	334	76%	796	2.38	2013.1	2016.7	2,713	3.4	2.23	7.6	2.92	1.0
Keyword ("Agric*") in objective	113	79%	270	2.39	2012.8	2016.3	1,174	4.3	2.39	10.4	3.13	1.4
At least one author from Africa	62	77%	152	2.46	2012.6	2016.4	866	5.7	2.33	13.2	2.89	1.6
Objective referring to Africa	27	83%	73	2.72	2013.6	2017.3	181	2.5	2.17	5.3	3.30	0.8
Asia in objective	11	72%	28	2.51	2013.5	2017.3	104	3.8	1.92	7.2	3.10	1.2
Asian countries in objectives	7	89%	18	2.55	2013.3	2016.7	23	1.3	1.68	2.2	1.11	0.1
Per starting year												
2008 and before	26	67%	58	2.24	2008.0	2011.2	296	5.1	1.96	10.0	2.58	1.3
2009-2012	133	76%	320	2.41	2010.8	2014.4	1,378	4.3	2.36	10.2	3.08	1.3
2013-2016	111	76%	265	2.39	2014.5	2018.1	866	3.3	2.03	6.6	2.68	0.9
2017-2020	64	79%	153	2.39	2017.5	2021.3	200	1.3	3.07	4.0	2.50	0.3
Group 2: Research projects funded by the European Commission (FP7 and H2020) with at least 1 paper in Agricultural Research for Development												
Total	2,516	35%	8,932	3.55	2012.8	2016.4	63,289	7.1	2.15	15.3	2.63	1.9
Funding amount < 600 K	584	57%	122	0.21	2013.1	2015.6	2,816	23.1	2.28	52.5	2.94	6.8
Between 600 K and 2.4 M	738	32%	1,234	1.67	2012.9	2017.0	13,616	11.0	2.27	25.1	2.69	3.0
Between 2.4 M and 4.8 M	667	28%	2,281	3.42	2012.1	2015.9	15,777	6.9	2.14	14.8	2.71	1.9
> 4.8 M	527	25%	5,294	10.05	2013.1	2017.2	33,564	6.3	2.17	13.8	2.63	1.7
Between 600 K - 4.8 M	1,404	30%	3,515	2.50	2012.5	2016.5	29,006	8.3	2.19	18.1	2.69	2.2
Keyword ("Agric") in objective text	249	49%	619	2.49	2012.4	2016.1	3,691	6.0	2.38	14.2	3.03	1.8
& at least one author from Africa	79	48%	206	2.61	2012.2	2016.0	1,508	7.3	2.61	19.1	3.18	2.3
& objective referring to Africa	35	48%	92	2.62	2012.9	2016.6	474	5.2	3.09	15.9	3.61	1.9
& Asia in objective	10	38%	24	2.43	2012.2	2016.3	158	6.5	3.90	25.4	4.11	2.7
& Asian countries in objectives	7	40%	21	3.03	2011.3	2015.0	134	6.3	4.12	26.0	3.74	2.4
Per starting year												
2008 and before	127	25%	337	2.66	2008.0	2011.8	3,610	10.7	2.47	26.4	2.67	2.9
2009-2012	608	29%	1,577	2.59	2010.6	2014.5	13,749	8.7	2.19	19.1	2.80	2.4
2013-2016	528	29%	1,258	2.38	2014.5	2018.6	10,838	8.6	2.06	17.7	2.49	2.1
2017-2020	141	46%	342	2.43	2017.5	2021.3	1,389	4.1	2.17	8.8	2.52	1.0

Note: One BEAF project with an unknown date and funding amount was excluded from the disaggregation per period. For the whole period, EUR 1.22 million (the average amount per project) was added to the amount funded to account for this missing value. The funding amounts were adjusted for inflation using the Consumer Price Index (2019 = 100; OECD (2020), "Inflation (CPI)" (indicator), <https://doi.org/10.1787/eee82e6e-en> (Accessed on 09 December 2020)). The indicators from this table should be interpreted cautiously given intrinsic limitations highlighted in the main report (e.g., differences in recall rates, differences in scope and regional foci between BEAF and comparators).

Source: Prepared by Science-Matrix using Scopus (Elsevier) data, data provided by GIZ, and OpenAIRE data

3 Conclusions

The figures presented in this report reveal a positive picture regarding the scientific impact of the BEAF-supported research. The BEAF lead on this dimension was nearly systematic across the selected indicators and most of the comparator groups. BEAF scientific impact was generally consistent with the aggregate figure for the group of 15 institutions of similar priority. BEAF's performance in impact was notable when publications produced by the IARCs but not supported by BEAF were used as reference. BEAF impact was also higher than the impact of the research falling in the same topics of prominence. Altogether, this points to highly influential research being supported by BEAF, at least as measured through citation-based indicators.

The BEAF degree of international scientific collaboration also stood out from that of most of the comparators, except for the other IARC publications, which scored similarly. One compelling factor to explain such performance could be that BEAF research takes advantage of the existing IARC networks, which would result in both groups scoring similarly and above the comparators in this dimension. When scientific collaboration is measured by the number of authors and by public-private co-publications, the lead of BEAF and the IARCs seems to be less pronounced but is still present to some degree. BEAF publications scored above world level and similarly to all comparator groups for share of OA.

The content analysis revealed that BEAF and the IARCs are more aligned to the content of the SDGs compared with the top institutions and those of similar priority. The most notable contributions of BEAF-funded publications to the SDGs were related to SDG 2 "Zero Hunger" (407 out of 888 papers).

The cost-effectiveness indicators presented in this report suggested that BEAF-supported projects may be outperforming other projects with similar scope. However, extra caution is advised in interpreting the comparisons provided under the cost-effectiveness section.

Appendix—Methods

Database used

This report uses bibliometric data retrieved from the Scopus database, produced by Elsevier. Scopus provides comprehensive coverage of the scientific literature. It contains bibliographic records for roughly 44 million peer-reviewed publications, from 1996 to the present, of the following document types which are covered in this study: journal articles, reviews, short surveys and conference papers. These document types are collectively referred to as “publications” or “papers” in this report. These publications span 50,000 peer-reviewed journals across 174 disciplines. Scopus indexes the names and affiliations of all authors on publications enabling the analysis of collaboration patterns, as well as the references of all publications enabling an analysis of their influence within the scientific community through citation-based metrics.

Unless stated otherwise, the tables and figures deriving from Scopus data include all the aforementioned document types. The topics of prominence in science,¹³ employed to support the content analysis (Section 2.3), are an integral part of Scopus. They can broadly be described as clusters of papers that share a common topical interest as measured by citation links. The version of Scopus used for this project, which has been conditioned by Science-Metrix to produce bibliometric indicators at a large scale, was found to be 95% “complete” for the year 2019. This meant that data could be included up to and including 2019 in this study.¹⁴

Construction of study data sets

This report is based on peer-reviewed publications retrieved from Scopus and published between 2001 and 2019. A list of BEAF-supported publications was used to delineate the set of relevant Scopus records. To identify the universe of global publications that fall within the larger subfield of “agricultural research for development” where BEAF projects were most active, a series of thematic queries were developed (see Section 0). Comparator selection was informed by initial statistics computed within this thematic set. The sections below detail the methods used to select the set of BEAF-supported publications and its comparators.

BEAF-supported publications: The BEAF-supported publications were retrieved from Scopus based on a list of publications provided by GIZ. This list of publications was made available in an Excel file in which each publication was linked to an IARC, a research project and the corresponding project’s characteristics, such as regions, countries and budget. Not all research outputs provided in this list could be matched to Scopus, which mostly comprises publications from peer-reviewed journals or conference proceedings. Some of the research outputs listed in the GIZ file corresponded to other types of scientific

¹³ <https://www.elsevier.com/solutions/scival/releases/topic-prominence-in-science>

¹⁴ There is a variable time lag between publication of a paper and its indexation in the Scopus database. As a result, papers are not necessarily included in the Scopus database in the year of their publication. In fact, many papers (especially those published in the final quarter of each year) are only included in Scopus the following year. Our tests on the version of Scopus used for this report indicated that 95% of the papers published in 2019 (in journals covered by Scopus) were already indexed in the database (i.e., that the database was 95% complete for that publication year), which was sufficient coverage to include publications from 2019 in the present study.

outputs such as theses, reports, workshop presentations, papers in preparation or papers that were too recently published to be covered in the current Scopus version. Notwithstanding the relevance of these research outputs, the findings reported here refer to those scientific publications that could be matched to Scopus, which is necessary for computing the bibliometric indicators.

During the data preparation phase of this project, it was observed that the list of scientific publications provided by the client was not fully comprehensive, although this is quite a common occurrence among funding sources. Nevertheless, this list accounted for most of the materials used in computing the indicators presented in this report (i.e., for 84% of the 888 scientific publications used in this report). The additional papers (N=139) that were not in the client list came from searches in the funding acknowledgements of publications in Scopus. The addition of papers to the GIZ list was only possible when the BEAF name (or a variation) and a reference to one of the projects in the GIZ file (by code or name) could be found simultaneously in the acknowledgements text. About 400 IARC publications were found to be referencing BEAF but missing a clear reference to a project. These cases could not be considered in this report (either as BEAF-supported publications or as other IARC publications) since we could not safely establish their correct group.

In another exercise, described in the inception report, we took GIZ's list of publications matched to Scopus and cross-checked it with the BEAF-supported publications retrieved using the Scopus acknowledgements section (based on references to BEAF and the project). This exercise resulted in a rough estimate of 776 BEAF-supported publications that may not have been considered in this study. It should be noted that this degree of incompleteness is commonly observed across other funding sources and that the list of publications provided by the GIZ and complemented using the Scopus acknowledgements section already provided reliable estimates for the indicators of research impact and collaboration in this report.

Also, as exemplified in the inception report, a few duplicated publications or some that were not up to date were identified in the GIZ list (e.g., publications that have been published in peer-reviewed journals but that were still characterized as being "in preparation" or named using previous versions of the research titles). This is a common situation among funding bodies, and it is mostly caused by the lack of a comprehensive database of scientific research that can serve as the main reference to characterize the outputs reported by the research centres as peer-reviewed scientific publications.

One recommendation that should help future bibliometric assessments of this nature would be for GIZ/BEAF to provide their supported researchers with a clear guideline on how they should acknowledge BEAF in their publications. Such a guideline should, at a minimum, provide a standardized format for enabling the unambiguous retrieval—from unstructured text often including acknowledgements to multiple funding sources—and classification of BEAF-supported papers by project. The key pieces of information needed for such a task are a uniform spelling of BEAF (including the full name and the acronym¹⁵), the contract/project numbers, and the contract/project titles (the fields retained in the standard format could be separated by semi-colon). Once efficient mechanisms are set in place to ensure such a guideline is rigorously followed by awardees, various solutions (some more

¹⁵ BEAF alone could hold different meanings.

customizable than others) suiting different budgets exist to periodically track new publications arising from a given source of funding.

The final list of BEAF-supported research used in this study contains 888 peer-reviewed papers published between 2001 and 2019 and retrieved from Scopus. It was possible to compute citation-based indicators of impact for 726 of these papers as they were published between 2001 and 2017 (see Section 0 for details).

Other IARC publications: The 17 IARCs that are partially funded by BEAF were selected as one series of comparators since they should produce publications that are close in scope to the BEAF-supported output. Papers from these IARCs were retrieved using the authors' affiliations indexed in the Scopus database. Only the publications that were not supported by BEAF were kept in this group, enabling comparison between those publications that were supported by BEAF and those that were not (possibly supported by other funders). The resulting data set contains 29,349 peer-reviewed publications from 2001 to 2019.

Thematic data set on agricultural research for development: The thematic data set on agricultural research for development was produced using keywords that were identified as highly relevant to this field of science. These keywords were searched in Scopus (i.e., in publication titles, abstracts and keywords). The definition of agricultural research for development provided by GIZ (research on innovative solutions to promote sustainable agricultural production, food and nutrition security, income generation, and sustainable natural resource management), and GIZ website,¹⁶ helped identify a set of core terms and specialist journals which were used in retrieving an initial set of relevant publications in Scopus. These publications worked as a “seed data set” to be further expanded.

This initial set of publications was used to identify other keywords that were highly specific to agricultural research for development (i.e., their relative frequency in this seed was much higher than in Scopus overall). Each of these terms was assessed based on the number of new papers they added to the data set as well as on a preliminary assessment of their relevance to the thematic area. This was an iterative process, and as new papers were added to the data set, new relevant terms were also identified, which again retrieved new papers. This process was repeated until an estimated recall¹⁷ rate of at least 70% was achieved. After this point, new terms usually only marginally increase the size of the data set while reducing its overall precision.¹⁸ In the end, a random sample of 100 papers was used to assess the precision of the resulting data set. At this stage, some refinements can still be made (e.g., when a paper is identified as not belonging to the data set, the pertinence of the respective queries is reassessed). Once this process was completed, the data set was further validated by a different analyst looking for potentially missed

¹⁶ <https://www.giz.de/en/worldwide/72136.html>

¹⁷ The recall rate is defined here as the proportion of all papers in agricultural research for development (in Scopus) that were included in the thematic data set. Since the (true) number of papers belonging to this category is unknown, the recall rate is estimated based on the proportion of papers from selected journals (e.g., *Field Crops Research*, *Crop Science*, *Journal of Applied Entomology*, *Biological Control*, *Experimental Agriculture*, *Crop Protection*) that are included in the data set.

¹⁸ *Precision* is defined here as the proportion of papers in the sample that are considered to fit into the definition of the data set, since the keywords used in the queries may have been used in a different context.

areas of relevance to the subject, for new terms, as well as for false positives (i.e., irrelevant publications retrieved by the selected keyword-based queries).

This data set consisted of 934,727 publications. Between 70% and 85% of the publications in relevant journals in this field and in the set of publications retrieved for the IARCs were captured in this data set through our keyword-based queries. Based on our experience, this range of recall rates is adequate in providing a proper world reference against which to benchmark scientific performance in a given area. Increases in recall beyond this point are most often offset by concomitant drops in precision (i.e., the share of irrelevant publications increases), and we favour precision over recall. Based on a random sampling of 100 publications from this thematic data set, precision was estimated at between 92% and 97%, meaning that 3% of these papers were not considered pertinent to the field and 5% were papers situated at the edge of the field.

The accompanying Excel databook lists the most common journals and authors in this thematic data set. Not all publications from these journals and authors are included in the data set, but only those containing the relevant keywords used as inclusion criteria. They nevertheless help portray the content of this data set, which was later used to identify institutional comparators for BEAF (see Section 0).

This process to create thematic data sets was also employed to generate the SDG data sets that support the content analysis in Section 2.3. The scope of the SDG data sets is broader than that of the thematic data sets. They are part of a recent effort within Elsevier to classify the publications in Scopus according to their contribution to each SDG. These SDG data sets were used in this report to assess the alignment of each group of publications (BEAF's and comparators') with the SDGs.

Thirty key players on agricultural research for development: Prominent research institutions on agricultural research for development were selected to provide additional comparators for the BEAF-supported research. The top 15 institutions¹⁹ in terms of number of papers were disambiguated in Scopus based on the authors' affiliations. In addition, 15 other institutions²⁰ were selected by the GIZ project management team and their publications were also retrieved from Scopus. Only these institutions' publications belonging to the data set on agricultural research for development were selected, thereby making it possible to compare BEAF-supported publications with other publications that were similar in scope. This report mostly focuses on the aggregate figures of these two groups of institutions as comparators (referred to as "Top Institutions on AgriRes" and "Institutions of Similar Priority" in the

¹⁹ The group of top institutions is formed by Agriculture and Agri-Food Canada (AAFC), the Brazilian Agricultural Research Corporation, the Chinese Academy of Agricultural Sciences, the Chinese Academy of Sciences, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the French National Centre for Scientific Research, the Indian Council of Agricultural Research (ICAR), the Nanjing Agricultural University, Northwest A&F University, the Spanish National Research Council, São Paulo State University (UNESP), the University of Florida, the US Department of Agriculture (USDA), the University of São Paulo (USP), and Zhejiang University). Note that three institutions that were included in the group of 15 institutions of similar priority were excluded from the group of top institutions (China Agricultural University, the French National Research Institute for Agriculture, Food and Environment (INRAE), and University of California, Davis).

²⁰ This group is formed by Agro ParisTech, China Agricultural University, Cornell University, ETH Zürich, the French Agricultural Research Centre for International Development, the French National Research Institute for Agriculture, Food and Environment (INRAE), Michigan State University, the Natural Resources Institute at the University of Greenwich, the Swedish University of Agricultural Sciences, the Thünen Institute, the Universität Hohenheim, the University of Bonn, the University of California, Davis, the University of Göttingen, and the Wageningen University and Research Centre.

report's tables). In some cases, the institutional figures are presented to provide benchmarking points against which to assess the BEAF performance. The accompanying Excel databook provides the complete scores for each of these institutions and can be used to complement the analysis provided in this report.

Bibliometric indicators

Citation impact indicators

The indicators of scientific impact used here are based on citations. An important assumption underlying such analyses is that citations are a good proxy for contributions to scientific knowledge. While it is true that citations are generally used to communicate the positive influence of one piece of research on another, citations are also sometimes used for other reasons. For example, one article may be contradicting another; the author would in that case use a citation to highlight the article being contradicted. Additionally, an article may cite many others, with some material constituting general background information and other material constituting the principal foundation on which the new piece of knowledge is built. These varying citation behaviours are all treated equally in analyses of scientific impact, which are blind to the differences between them.²¹

Scientific impact assessed on the basis of citations would therefore be better interpreted as contributions to and visibility within scientific discourse. In light of this, the interpretation of scientific impact analyses should proceed with due caution.

Because citation practices vary between the disciplines and sub-disciplines of science, simple counting of a paper's citations would create unwanted biases in the results. To correct these potential distortions, individual publications are evaluated relative to the average citation rate for publications in the same subfield and published in the same year. The normalization also accounts for the type of publication because review articles are usually more cited and include more references than research articles. This measure is known as the relative citation (RC) score or field-normalized citation score and is not directly reported in this study's analyses. Rather, it is instrumental in computing the average of relative citations (ARC), the citation distribution index (CDI), and the share of highly cited publications (HCP) presented below.

For all the indicators relying on the RC scores of papers, a certain amount of time must be allowed for the published work to have an impact on subsequent research and for articles to be cited. Ideally, we keep a minimum of two years following the latest year of publications used in computing these indicators. In this report, this means that the ARC, CDI and HCP indicators were computed accounting for papers up to and including 2017.

Average of relative citations: The ARC is the average of the RC scores of all the articles published by a given entity. The ARC is normalized to 1, meaning that an ARC above 1 indicates that the entity's

²¹ Aksnes, D. W., Langfeldt, L., & Wouters, P. (2019). Citations, citation indicators, and research quality: An overview of basic concepts and theories. *SAGE Open*, 9(1), p. 215824401982957. doi:10.1177/2158244019829575.

articles have higher-than-average impact, an ARC below 1 means that the entity's articles have lower-than-average impact, and an ARC near 1 means that the publications have near-average impact.

The ARC offers a simple and intuitive interpretation of the average impact of a publication set. However, because RC scores are known to be skewed in their distribution—with a small number of papers receiving a large share of the total citations—the ARC can be biased upward potentially resulting in a strong correlation with the HCP indicators; this risk increases as the data is disaggregated in finer units of analyses. Because the HCP indicator aims to monitor research excellence rather than average performances like the ARC, this issue can be problematic. For this reason, Science-Metrix complements the ARC with the CDI, described below.

Citation distribution chart and citation distribution index: The citation distribution chart (CDC) facilitates a simple but nuanced visual inspection of an entity's research impact relative to worldwide performance (in the same subfield, year and document type) (see Figure 3). To prepare these charts, Science-Metrix divides all publications in a given research area into 10 groups of equal size, or “deciles”,²² based on their RC scores. The 1st decile contains the 10% of publications with the lowest RC scores; the 10th decile contains the 10% of publications with the highest RC scores.

For a given research entity, it is expected that the RC scores of its publications will follow the global distribution, with an equal number of publications falling in each of the deciles. The CDC for a given entity compares that entity's scientific impact to the global level by showing how its performance compares to the world level in each of the deciles.

²² Two adjustments are made in order to ensure high-quality results, and these pertain to (a) cases where a number of publications are tied in their scores, and (b) cases where the total number of publications is not divisible by 10. For the first case, (a), papers tied at the margin of two deciles will be grouped together and then divided proportionately to ensure that each decile contains the right number of papers. In the case of the total number of papers not being divisible by 10, (b), papers will be fractioned to ensure that the deciles are always of exactly equal size.

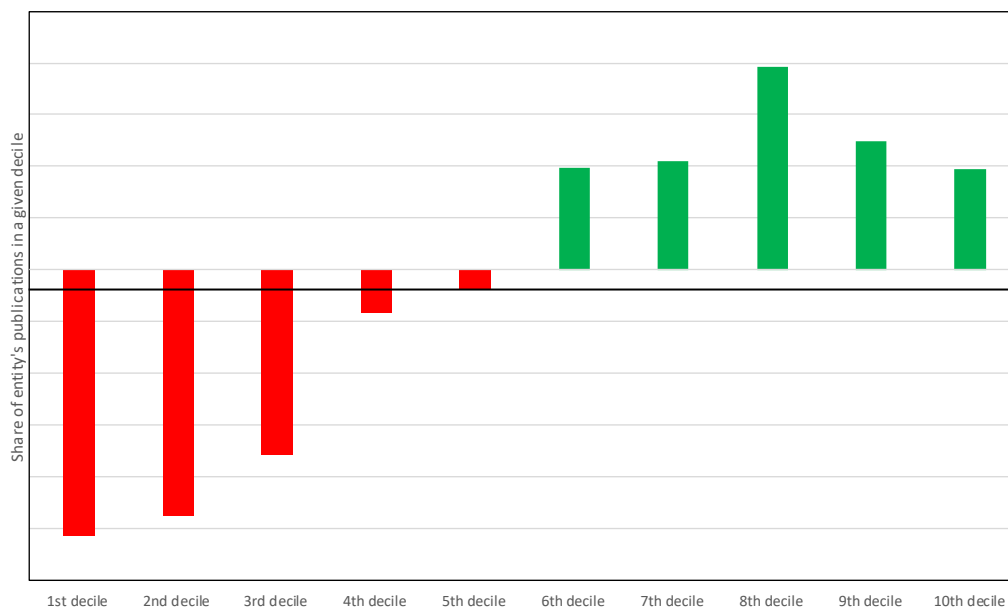


Figure 3 Sample of citation distribution chart

Source: Prepared by Science-Metrix

As shown in Figure 3, the CDC shows 10 colour-coded bars for a hypothetical entity; each bar represents the relative presence of this entity's papers in each corresponding decile. The world level, in contrast, is represented by the central horizontal line, with no bars, as it represents the uniform distribution of all the publications across the 10 deciles. The bar's colour shows whether the specific entity has more or fewer publications in that decile than expected (i.e., the horizontal line): a green bar denotes production exceeding expectation in that decile, and a red bar denotes production below expectation in that decile.

The length of the bar shows how far above/below expectation the entity is in that decile. The longer the red bar, the fewer the articles that are found in that decile relative to expectation. Conversely, the longer the green bar, the more publications are found in that decile, again relative to expectation. Cases where a decile has no bar associated with it show that the entity's performance is exactly in line with the expectation based on global performance. Accordingly, a CDC with no visible bars shows that the entity in question has 10% of its papers in the 1st global decile, 10% of its papers in the 2nd global decile, and so on, which, as previously noted, corresponds to the world distribution of papers based on their RC scores.

Ideally, one would hope to have more papers than expected in the highest deciles, where the most impactful publications are found; similarly, one would hope to have fewer papers than expected in the lowest deciles, where the least impactful publications are found. Thus, strong research performance is shown by long red bars on the left of the CDC and long green bars on the right of the graph. In contrast, weaker research performance is depicted with long green bars on the left side (indicating more publications than expected in the less impactful deciles) and long red bars on the right side (indicating fewer publications than expected in the more impactful deciles). Figure 4 presents various distributions related to best-case and worst-case scenarios.

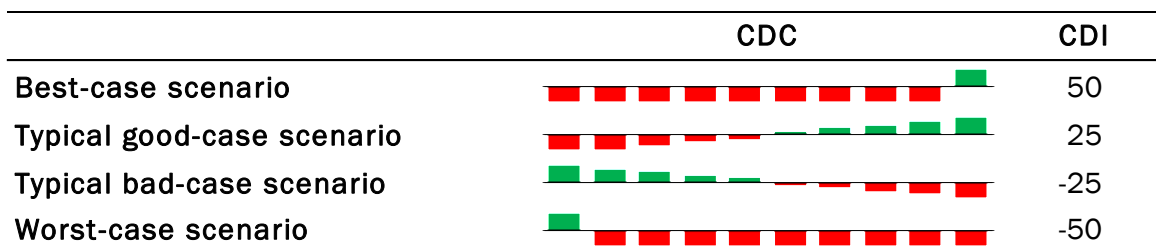


Figure 4 Various scenarios of citation distribution charts and their citation distribution index

Source: Prepared by Science-Metrix

The content of the CDC can also be summarized numerically using the CDI. For each decile, the performance of a given research organization is compared to the global average, and this ratio is then multiplied by a weight corresponding to that decile, as presented in Table X.

Table X Decile weighting to compute citation distribution index

Decile	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Weight	-5	-4	-3	-2	-1	1	2	3	4	5

Source: Prepared by Science-Metrix

Once a score has been produced in this fashion for each decile, the scores are summed to calculate the CDI for the research organization. Thus, having a higher-than-expected number of publications in the 1st decile (i.e., the lowest-impact decile) will reduce the CDI more than having a higher-than-expected number of publications in the 2nd decile. The CDI ranges from -50 (worst-case scenario) to 50 (best-case scenario) with 0 representing parity with the world level. Compared to mean-based normalized citation metrics, the combined use of the CDC and CDI makes it possible to provide reliable citation metrics even when dealing with entities having produced few publications (from 10 to a couple of hundred).²³

Highly cited publications: HCP are publications that have received RC scores among the highest in their respective field. Most commonly, the top 10% most cited publications (HCP_{10%}) are considered to examine research excellence, measuring how many high-impact articles are produced by a given research entity, relative to their expected contribution to world-leading research. A high concentration of all citations made (close to 45%) are attributed to this group of publications.²⁴ HCP can be further restrained to the top 1% to increase the focus on those few exceptional papers that left a very strong imprint/legacy on the scientific community.

The HCP measure is normalized to 1, meaning that an entity with an HCP over 1 contributes more than its expected number of highly cited papers, an entity with an HCP below 1 contributes fewer than its

²³ Campbell, D., Tippett, C., Côté, G., Roberge, G., & Archambault, É. (2016). An approach for the condensed presentation of intuitive citation impact metrics which remain reliable with very few publications. In I. Rafols, J. Molas-Gallart, E. Castro-Martínez, & R. Woolley (Eds.), *Proceedings of the 21st International Conference on Science and Technology Indicators*, pp. 1229–1240. Valencia, Spain. doi:10.4995/STI2016.2016.4543.

²⁴ Bornmann, L., Leydesdorff, L., & Wang, J. (2013). Which percentile-based approach should be preferred for calculating normalized citation impact values? An empirical comparison of five approaches including a newly developed citation-rank approach (P100). *Journal of Informetrics*, 7(4), pp. 933–944. Retrieved from <http://arxiv.org/abs/1306.4454>.

expected number of highly cited papers, and an entity with an HCP near 1 contributes close to its expected number of highly cited papers.

Field-Weighted CiteScore: The Field-Weighted CiteScore (FWCS) is normalized to 1, meaning that an entity with an FWCS above 1 publishes in higher-than-average-impact journals, an FWCS below 1 means that the entity publishes in lower-than-average-impact journals, and an FWCS near 1 means that the entity publishes in near-average-impact journals.

FWCS and comparable impact factors are commonly used as a proxy for quality of research, with an added advantage that they can be computed sooner after publication than citation-based indicators can. The basic assumption here is that the global peer-review system ensures that higher-quality research “trickles up” to higher-quality journals (as captured by their FWCS). Therefore, a research group’s average CiteScores across its publications should, in principle, offer an additional angle to capture that group’s achievements in research quality.

It is important to note that the FWCS captures slightly different dimensions of quality than citation-based measures. In fact, citation-based quality (influence/impact) scores do not always converge with CiteScore-based performances. While journal peer reviewing should “filter” for quality at levels commensurate with the prestige of journals, CiteScore and citation-based measurements of quality at an institutional level can differ for the following reasons:

- Broad uptake in the scientific community depends on more than innovativeness strictly understood (i.e., papers can be cited for other reasons than the innovativeness that is the focus of peer review).²⁵
- Quality and innovativeness are moving targets given how criteria of excellence may themselves evolve with scientific achievements. Peer reviewers may not be able to predict which research will be of highest use in the (near) future.
- Submitting authors’ prestige, affiliation, gender, geographic origin and other personal features may sometime colour the peer-review process, and this even in journals where double-blind review processes are implemented.²⁶

In the end, Science-Metrix expects its FWCS measurements to capture a variable combination of experimental and scholarly excellence; journal editors’ and peer reviewers’ preferences in research priority; and submitting authors’ reputations and authority. FWCS measurements are best interpreted as part of a more comprehensive dashboard of indicators on research quality that include at least multiple citation-based dimensions as well. Interpretation of FWCS findings should be the subject of great caution where they meaningfully deviate from citation-based findings for a given group and period of analysis.

Other indicators

²⁵ Aksnes et al., Citations, Citation Indicators, and Research Quality: An Overview of Basic Concepts and Theories.

²⁶ Lee, C. J., Sugimoto, C. R., Zhang, G., & Cronin, B. (2013). Bias in peer review. *Journal of the American Society for Information Science and Technology*, 64(1), pp. 2–17. doi:10.1002/asi.22784; Reingewertz, Y., & Lutmar, C. (2018). Academic in-group bias: An empirical examination of the link between author and journal affiliation. *Journal of Informetrics*, 12(1), pp. 74–86. doi:10.1016/j.joi.2017.11.006; Petersen, A. M. (2019). Megajournal mismanagement: Manuscript decision bias and anomalous editor activity at PLOS ONE. *Journal of Informetrics*, 13(4), p. 100974. doi:10.1016/j.joi.2019.100974.

Shares of open access publications: OA as a topic in science policy has grown immensely in importance in recent years. The support of OA publication practices by policymakers and funders is regularly seen as an instrument in achieving increased public openness and availability for the outcomes of research. This is, in turn, expected to contribute to higher public engagement and societal outcomes originating from this research. Measuring the shares (%) of a given group's or institution's publications that have been made available under OA licensing can provide one line of evidence in appraising that entity's performance on openness, engagement and knowledge transfer dimensions.

1science, Science-Metrix's spin-off company, has constructed a database of peer-reviewed, OA publications using a web harvester to collect and characterize papers from the web. The definition being applied is a simple one: a publication is OA if it can be accessed for free and without any barrier, such as a subscription or registration. Although the findings produced with this indicator are simple, precisely and accurately identifying which scientific papers are available in OA is not a trivial procedure.²⁷ As an example, the harvester developed by Science-Metrix and 1science now retrieves information from more than 180,000 websites.²⁸

International collaboration rate: An international collaboration is defined for this project as any article that was co-published by authors from at least two countries. The international collaboration rate (ICR) of an entity is simply a measure of how many articles are co-published with international partners as a proportion of the given entity's total output. The ICR is obtained by dividing the number of international co-publications of an entity by its total number of publications. The citation advantage of international co-publication over domestic co-publication or single-author publications has been illustrated in numerous studies.

Share of public-private co-publications: This indicator shows the proportion of an entity's papers that are published in collaboration (i.e., co-published) between private and public institutions. It is based on an automated algorithm to identify private-for-profit institutions (usually companies and consulting firms). The collaborations classified under this as public-private are mostly representing collaborations between private-for-profit institutions and universities or public research centres.

Specialization index: The specialization index (SI) indicates how much output an entity produces in an area of research, adjusted for the entity's overall number of papers (in the thematic data set of agricultural research for development) and relativized to the world level (again in the thematic data set). For instance, if 20% of a given country's publications in agricultural research for development are in SDG2 (zero hunger), but at the global level only 15% of papers are in SDG2, then the country is said to be *specialized* in SDG2, producing proportionately more output in that area than is normally the case elsewhere around the world (SI = 1.33).

The SI reference value is 1 (i.e., the world level is always equal to 1); accordingly, an SI above 1 shows that an entity produces proportionately more papers than the average in a given area, an SI below 1 shows

²⁷ Piwowar et al., "The State of OA."

²⁸ Science-Metrix, "Open Access Availability of Scientific Publications."

that an entity produces proportionately fewer papers than the average in that area, and an SI near 1 shows that an entity produces close to the average proportion of papers in that area.

It is worth noting here that the SI is a zero-sum game because it is measured as a proportion of total output. If the proportion of an entity's output in one area increases, there must be relative decreases elsewhere. By definition, one cannot be specialized in all areas at once.

The SI is formulated as follows:

$$SI = \frac{(X_S/X_T)}{(N_S/N_T)}$$

Where

X_S = Publications from entity X in a given research area (e.g., papers by UK in SDG2)

X_T = Publications from entity X in a reference set of papers (e.g., total papers by UK in agricultural research for development)

N_S = Publications from reference entity N in a given research area (e.g., world papers in SDG2)

N_T = Publications from reference entity N in a reference set of papers (e.g., total world papers in agricultural research for development)

Cost-effectiveness: Three metrics of cost-effectiveness are used in this project.

- **Publications per million euro:** The ratio between number of publications found in Scopus and the amount funded (million euro).
- **Sum of normalized citation scores per million euro:** The ratio between the total citations received by a paper (normalized by the average of the subfield in a given year) and the amount funded (million euro).
- **Sum of highly cited publications (top 10%) per million euro:** The ratio between the number of publications in Scopus among the 10% most cited in their subfield and year and the amount funded (million euro).