An Acad Bras Cienc (2023) 95(Suppl. 2): e20230492 DOI 10.1590/0001-3765202320230492
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

HEALTH SCIENCES

Brazilian South-South Scientific Collaboration and The Sustainable Development Goals

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Abstract: We look at Brazilian collaboration in Scientific papers based on SciVal and Incites regarding the Sustainable Development Goals (SDGs) of the United Nations. Data were collected from InCites® and SciVal® (2012-2021). Groups of Global South countries were formed (ASEAN, Asia, Africa, BRICS, Caribbean, Central and Latin America). Analyses included Cluster (Author position, impact/citations, open access, journal quartil), principal component, path and analysis of variance to see the effect of region and SDGs in Brazilian publishing. Scopus data were analysed in Vosviewer® for creating country networks through publication, citation and bibliographic coupling, as well as keyword analysis. SDG 3 (Good Health and Well-Being) dominates all Brazilian scientific collaborations with the various country groups. While gender equality shows greater importance in ASEAN and African countries, Life Below Water (SDG14), on Land (SDG15), and Climate Action (SDG13), are important in all regions. SDGs 1, 8, 10, 12, and 16 show less importance in this collaboration overall. Brazil is relatively more active in Zero Hunger (SDG2) and Life on Land (SDG15) than worldwide. Brazil South-South collaboration in published documents shows higher impact than North South in some areas. Collaboration priorities vary by region and triangulation with countries is high depending on language and region.

Key words: ASEAN, Latin America, Africa, Impact, Assessment

INTRODUCTION

International collaboration is critical for the growth of scientific and technological research to meet the United Nations´ (UN) Sustainable Development Goals (SDG), especially in low- and middle-income countries (LMIC) (Fonseca et al. 2016). According to Rennkamp & Boulle (2018), knowledge emerges through the interaction of the various actors within networks through creation, adoption and transfer. The development of intellectual capital (Bratianu 2018) is fundamental to achieving these goals, including cooperation between all levels of implementation (Fonseca et al. 2020). The development and implementation of SDG targets need an alliance between science and policy (Leach et al. 2012). Science is at service to society (Griggs et al. 2014) as an advisor through mediating targets and producing knowledge. Decisions around complex issues such as water scarcity, ocean health, ecosystems and food security must be evidence-based (Glaser 2012) with relevant indicators (Hák et al. 2016). Therefore, science becomes a fundamental part of attaining the SDGs (Imaz & Sheinbaum 2017).

Luo et al. (2013) show that international partnerships often encounter barriers such as resource, capacity, political and cultural

differences which affect the motivations, balance of benefits, regulation of research, and ultimately outcomes of these programs. This makes relationships between collaborating regions in research important for attaining the goals. While North-South collaboration (NSC) may generate perverse effects in reinforcing the power asymmetry between northern and southern institutions, South-South Collaboration (SSC) is thought to incorporate more solidarity, complementarity and lack of hierarchy (Abdenur & Fonseca 2013). On the other hand, van der Veken et al. (2017) state that SS relations are more competition than collaboration.

Bibliometric analysis has been used to map educational questions related to the SDGs (Prieto-Jiménez et al. 2021). According to Severino et al. (2021) the number and quality of publications is one proxy that can be used to infer efforts made to attain SDGs. Keyword network analysis has been used to support the identification of overarching areas in need of integrated implementation to support the ultimate goal of sustainable development (Lim et al. 2018), social network analysis has been employed to understand the structure of water-energy-food nexus governance (Kurian et al. 2018), and to compare SDG network compositions for different country income levels (Lusseau & Mancini 2019).

In the present paper, we characterise South-South Cooperation in scientific collaboration between Brazil and other developing countries in Latin America, Africa and Asia. It is understood that this type of partnership should enrich all the actors involved, not only in the academic-scientific aspect but also in the exchange of cultural, ethical and social values. Furthermore, we recognise that the expansion of scientific knowledge is more than ever a global undertaking, which must go beyond the countries of the North, recognising that there are different problems in different societies and that, to solve them, the participation of different perspectives is essential and complementary.

MATERIALS AND METHODS

Data were collected in two databases – InCites® based on the Web of Science (Clarivate Analytics) and SciVal® based on Scopus (Elsevier) from 2012-2021. Groups of Global South countries were formed (ASEAN, Asia, Africa, BRICS, Caribbean, Central America and Latin America). The scientific international collaboration of these groups with Brazil was studied by Sustainable Development Goal as follows:

SDG1: no poverty;
SDG2: zero hunger;
SDG3: good health and well-being;
SDG4: quality education;
SDG5: gender equality;
SDG6: clean water and sanitation;
SDG7: affordable and clean energy;
SDG8: decent work and economic growth;
SDG9: industry, innovation and infrastructure;
SDG10: reduced inequalities;
SDG11: sustainable cities and communities;
SDG12: responsible consumption and production;
SDG13: climate action;
SDG14: life below water;
SDG15: life on land;
SDG16: peace, justice, and strong institutions; and
SDG17: partnerships for the goals (not analysed).

Countries were also joined into two groups (Global North (N_) and Global South (S_)) in accordance with the United Nations Finance Center for South-South Cooperation[1].

[1] http://www.fc-ssc.org/en/partnership_program/south_south_countries

Data included % of documents cited, % top 1% and 10% of citations, citation impact (CI – number of citations per paper), % Hot Papers (top 0.1% of papers by citations for field and age, with papers that are less than two years old), % High (% of papers in top 1% of citations compared with papers in same field and age), Impact Relative to the World (IRW-citation impact/world citation impact), Average Percentile (AP – how a paper performed relative to others in the same field, year and document type. Lower is better), % documents in Q1, Q2, Q3 and Q4 journals (Quartiles (Q) are calculated from the rank of a Journal Impact Factor relative to the total number of journals in the category), % of documents with industry collaborations, CNCI (Category Normalised Citation Impact -divide the count of citing documents by the expected citation rate for documents with the same document type, year of publication and subject area), JNCI (Journal Normalized Citation Impact -normalizes the citation rate for the journal in which the document is published) , Brazilian author position in the paper (first, last or corresponding), and Type of publication (% Gold, Gold-Hybrid, Green, Open Access, Free to Read, Not OA). The declared funding source was also investigated.

Analyses included Cluster (by Author position, impact/citations, open access, journal quartile), principal component, and analysis of variance to see the effect of region and SDG in Brazilian publishing in SSC. Path Analyses (PROC CALIS) were also carried out by global region collaboration. Data were analysed in SAS v9.4 (Statistical Analysis System Institute, Cary, North Carolina).

Collaboration networks were created through defining publications in Scopus of Brazil with the groups (2012-2021). These were then analysed in Vosviewer® version 1.6.18 (van Eck & Waltman 2010) for creating country networks through publication, citation and bibliographic coupling, as well as keyword analysis.

RESULTS

In terms of Brazil-SSC there were 2,030 documents with Central America, 28,428 with South America, 2,457 with the Caribbean, 9,776 with Africa and 24,343 with Asia. In terms of Scientific publications (Figure 1), Clinical & Life Sciences (CLS) and Physics dominate collaboration in all regions. The lowest % of CLS is with BRICS (30.7%) and the highest with ASEAN countries (41.52). With all regions, Arts and Humanities represented less than 1% of publications. Agriculture, Environment & Ecology (AEE) showed a higher % of collaborations with Latin (22.9%) and Central American (23.3%) countries, and lower with Arab (9.7%), ASEAN (11.5%), Asia (12.3%) and BRICS (11.7%) countries. CLS, AEE, Physics and Chemistry accounted for almost 85% of the collaboration. Concerning CNCI, Arts and Humanities had the highest impact (but very few documents), followed by CLS and AEE. BRICS (10.7) and ASEAN (6.2) countries showed the highest impact in CLS and AEE (8.8 and 4.1, respectively). Impact with Central America and the Caribbean was lowest overall.

SDG 3 dominates all scientific collaborations of Brazil with the various country groups (Table I and Supplementary Material - Figure S1). While gender equality shows greater importance in ASEAN and African countries, Life below water (14) and on Land (15), as well as climate action (13), are also important in all regions. SDGs 1, 8, 10, 12, and 16 show less importance in this collaboration overall.

The influence of Global North countries is evident even when only Global South collaborations with Brazil were investigated (Figure 2). This collaboration can help improve impact (Figure 2c).

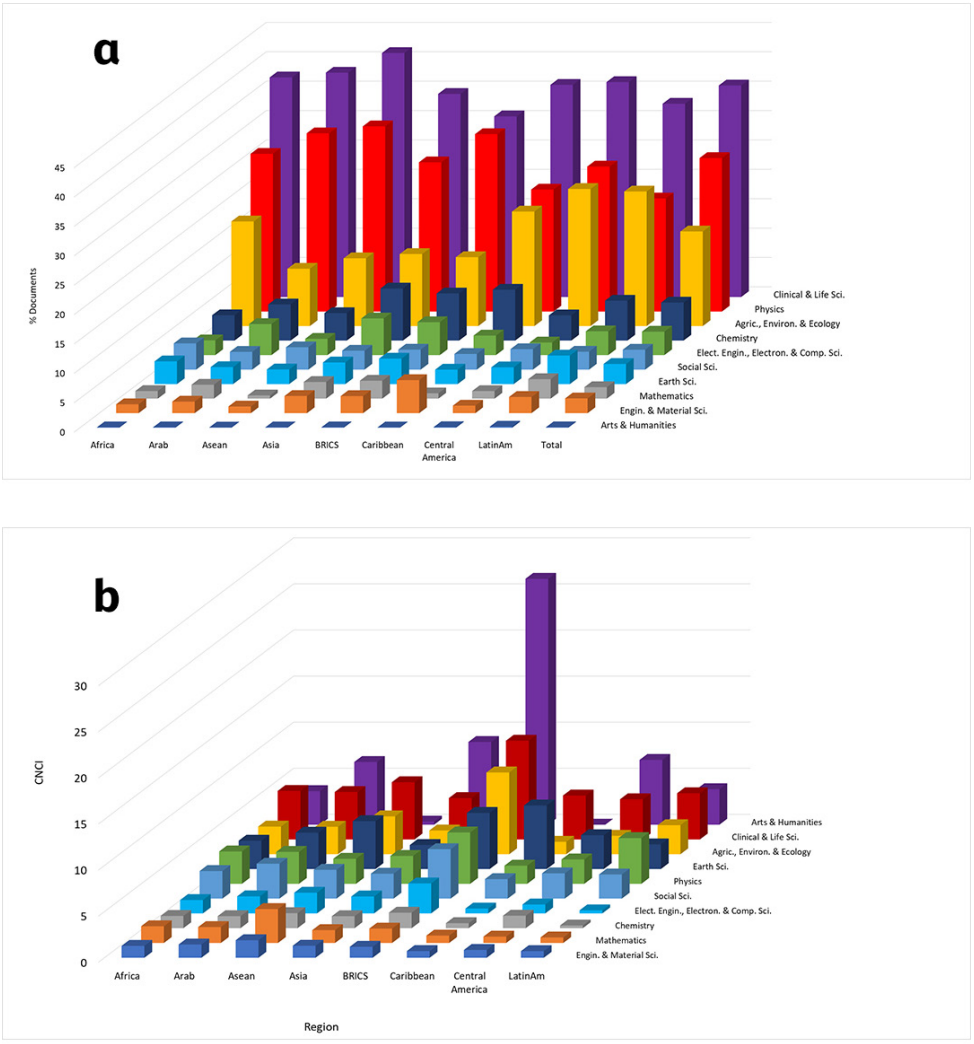


Figure 1. Percentage of Documents by Brazilian Authors in Global South Collaboration (a) and their Impact (b) by Knowledge Area.

With ASEAN countries (Figure 3), most publications have an impact > 1. On the other hand, impact with BRICS, Asia, and the Arab States vary from 0.5 to 4. Collaboration of Brazil with Central America, South America, Africa and the Caribbean are classified by a higher percentage of non-cited documents, and CNCI concentrated in 0.25 to 2.

Brazil is a major author in collaboration (around 40% as first, last or corresponding author) with the Caribbean and South America (Table II), around 30% with Central America, and 20% with the other country groups. With worldwide collaborations, Brazil is a major author in over 80% of its collaborative works.

In terms of publications by SDG (Table III), Brazilian authors are more prominent in Affordable Energy (7), Clean Water (6) and Industry (9), with around 40% of major authorship. Lower percentages (<30%) are seen for No Poverty (1), Gender Equality (5) and Peace (16).

Higher percentages of Brazilian authors (Figure 4) tend to publish more in Q3 and Q4 journals, with lower impact (CNCI, % High, % Hot, IRW, AP) and lower industry collaboration.

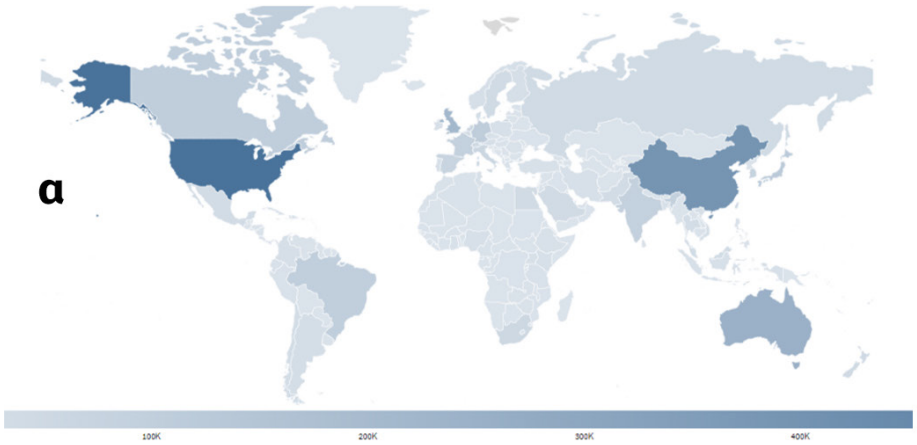


Figure 2. Geographical distribution (2012 – 2021) of Global South Collaboration Publications with Brazil (a); Number of publications (b); their Impact (c); and Industry Collaborations (d) (InCites®).

Table I. Percentage Publications per SDG and Country Group in Collaboration with Brazil.

	Latin America	ASEAN	BRICS	Africa	Asia
01 No Poverty	0.24	0.53	0.57	0.86	0.31
02 Zero Hunger	4.00	3.81	3.15	4.77	3.53
03 Good Health and Well-being	48.15	52.94	51.63	45.88	49.68
04 Quality Education	1.36	1.26	1.20	1.54	1.15
05 Gender Equality	6.36	8.69	6.47	9.08	6.56
06 Clean Water and Sanitation	3.72	2.09	3.28	3.66	3.02
07 Affordable and Clean Energy	2.81	1.40	2.63	1.26	1.96
08 Decent Work and Economic Growth	0.34	0.30	0.51	0.35	0.40
09 Industry	1.67	1.24	1.80	1.14	1.51
10 Reduced Inequality	0.53	0.44	0.46	0.60	0.39
11 Sustainable Cities and Communities	3.66	2.91	4.23	2.93	3.77
12 Responsible Consumption and Production	1.31	0.82	1.35	1.11	1.31
13 Climate Action	7.16	7.64	7.27	7.57	7.94
14 Life Below Water	9.29	8.12	7.90	9.45	9.37
15 Life on Land	9.16	7.70	7.40	9.52	8.98
16 Peace and Justice Strong Institutions	0.23	0.11	0.15	0.27	0.14

A lower percentage of documented cited (Table IVa) was seen with quality education (SDG4), reduced inequality (SDG 10) and peace (SDG 16). These were accompanied by a lower percentage of papers that were highly cited, with industry collaborations and published in Q1 journals. The opposite can be seen for Good Health (SDG 3), Gender Equality (SDG 5) and No Poverty (SDG 1).

There was lower industry collaboration with South American and Caribbean countries (Table IVb), accompanied by lower impact. These countries tended to publish in journals with lower JNCI. There were higher citation rates with Asian, ASEAN, Arab and BRICS countries. Collaboration with Africa saw a higher % of papers in the Top 1%, more industry collaboration and a higher % of papers in open access (see also Tables SIa and SIb).

Different publication concentration and impact is seen depending on SDG and country region (Table SII). SDG3 is the most prevalent in all regions. Nevertheless, it is higher with Arab countries than with Central & North America and Africa. Zero Hunger (SDG2) is higher with Africa (double World mean). Life on Land (15) and Life below Water are also higher than World Mean, especially with Africa and South America. Climate Action is also above world mean as expected, except for Caribbean and Arab countries. SDGs 1, 8, 10, and 16 are less than 1% of all collaborations. Impacts were higher for SDGs 1 to 5 and lower with the Caribbean and South American countries. Comparing NSC and SSC (Table SIII and Figure S1), some differences are seen for indicators in different SDGs such as authorship (SDGs 1, 3, 4, 5, 6, 7, 10, 11, 13 and 14), Open Access (be it Gold, hybrid or green: 1, 3, 4, 5, 7, 8 9, 10, 12, 14), and journal quartile (1, 5, 8, 9, 13, 16). Only SDGs 3, 5 and 11 showed differences in CNCI, with higher values for SSC. SSC had relatively less industry collaboration in SDGs 2, 3 and 6 and less hot papers in SDGs 2 and 4.

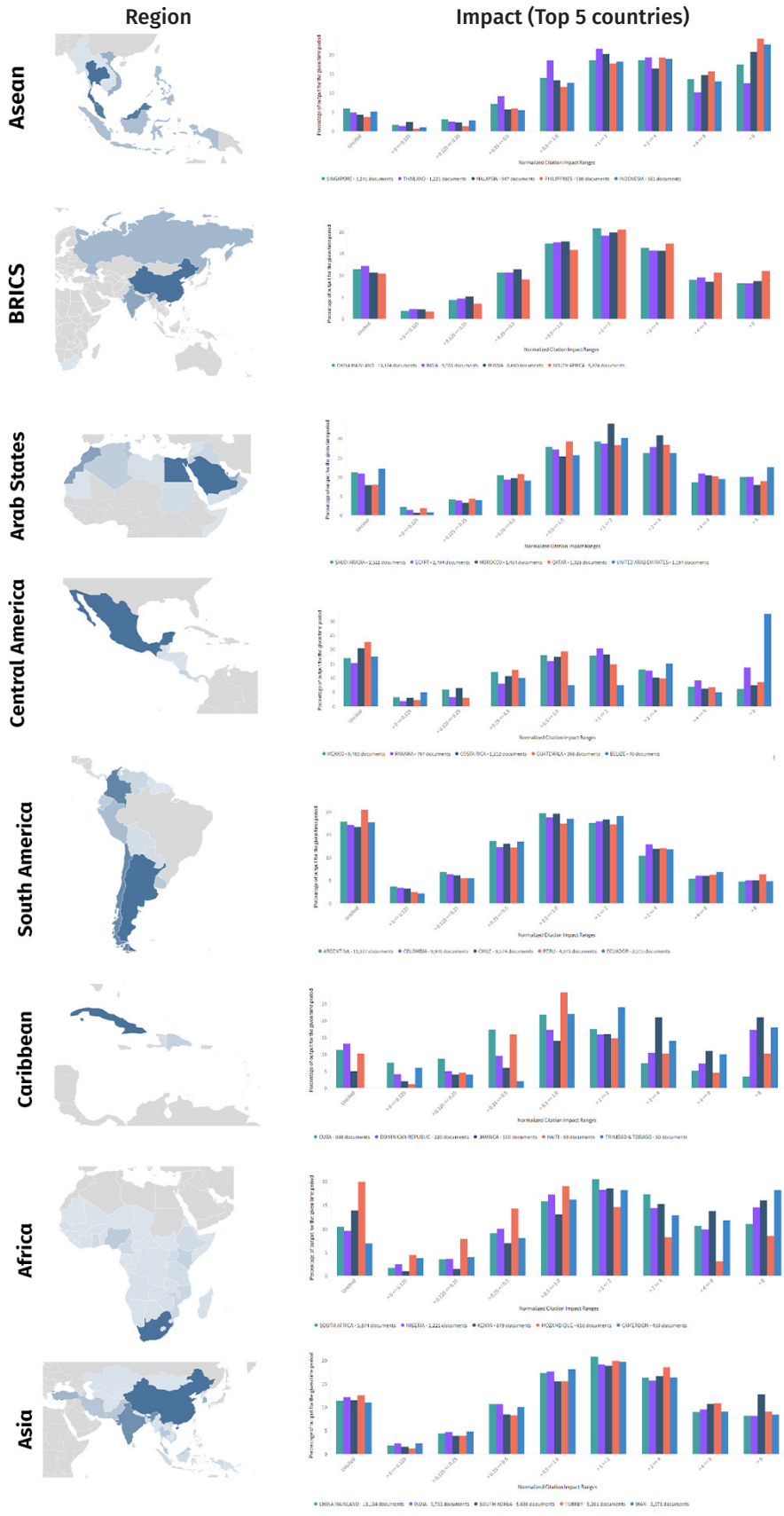


Figure 3. Number of Papers in Web of Science data base (left column) and Citation Impact by Region (right column) in collaboration with Brazilian authors (2012-2022).

Table II. Percentage of Brazilians by Collaboration Author Type by Regional Group.

	% First	% Last	% Corresp
Africa	22.40[d]	22.30[de]	22.28[de]
Arab	20.70[d]	24.96[cde]	22.07[de]
ASEAN	14.54[e]	17.68[e]	17.02[e]
Asia	18.84[de]	24.61[cde]	19.42[e]
Brazil with world	82.39[a]	73.85[a]	80.99[a]
BRICS	20.74[d]	24.71[cde]	21.98[de]
Caribbean	42.05[b]	29.51[cd]	41.90[b]
Central America	28.46[c]	31.25[c]	26.49[d]
South America	39.24[b]	39.34[b]	36.47[c]

Numbers in the same column followed by different letters are significantly different using SNK (P<0.05).

Brazil is relatively more active in SDGs such as Zero Hunger (SDG2) and Life on Land (SDG15) than worldwide. SDGs 6 and 12 are approximately 50% above the world mean. Most others are close to the world mean, with only SDG7 slightly below the mean (0.75).

There are similar patterns for the clusters of groups of countries by SDG (Figure S2), as seen earlier (Table IV). Collaborations with Central and South America as well as Latin America tend to have a lower impact. The BRICS and Africa change cluster depending on the SDG. SDG1 and SDG5 they are in the low impact group, while for SDG6, only Africa is in the low impact group.

On the other hand, looking at clusters of collaboration by country group (Figure S3), there are changes in regional focus (Table SI). Brazil shows a high impact in gender equality (SDG5) with almost all regions (lowest with South America). Other SDGs where Brazil strongly impact collaboration are No Poverty (SDG1) and Good Health (SDG3). With Africa, Decent Work and Economic Growth (SDG8) also has a high impact. The impact is generally poor for all SDGs with South America and the Caribbean, although the Caribbean shows a higher impact for Sustainable Cities and Communities (SDG11). Central America shows a higher impact for Peace (SDG16).

High participation of the United States can be seen in all maps (Figure 6). Mexico strongly influences Central America and The Caribbean, while China is seen in ASEAN and Asian groups as expected. Africa has a varied collaboration base, with a dominance of South Africa. Brazil´s collaboration with South America, Argentina, Chile and Colombia are highlighted, along with the USA, Spain, the UK and France. With BRICS, as expected, China and India are prevalent.

CNPq, CAPES and FAPESP are responsible for over 81% of the declared financing by Brazilian agencies (Table SIV), of which 78% are in Latin America, followed by Asia Pacific and Africa. Collaborative funding with BRICS is relatively low. CNCI differs by agency and region (Table SV), with FAPDF having the highest impact in BRICS countries (16.64). The highest impact overall was seen with ASEAN or African countries.

Looking at international funding for Brazilian papers in collaboration (Figure 7), once again, the USA is prominent, along with the European Union (Table V), Germany and Russia. Much funding comes from agencies involved with Energy, Nuclear and Atomic Research, such as the US Department of Energy, Joint Institute for Nuclear Research, Instituto Nazionale di Fisica Nucleare, Centro de Aplicaciones Tecnológicas y Desarrollo Nuclear, Commissariat à l'Énergie Atomique et aux Énergies Alternatives, Department of Atomic Energy, Government of India, Institutul de Fizică Atomică among others.

Private funding included that from pharmaceutical companies such as Pfzier, Astra Zenica, Glaxo Smith, Merck, Sanofi and Novartis. This was a higher percentage for collaborations with African (2.4% of total papers financed) rather than South American (0.5%) and Arab (0.6%) countries. Philanthropic foundations are also active, such as Bill and Melinda Gates,

Table III. Percentage of Brazilians by Author Type by SDG.

	% First	% Last	% Corresp
01 No Poverty	24.87^{cd}	21.71^{e}	24.81^{de}
02 Zero Hunger	32.24^{abcd}	31.45^{bcde}	32.47^{abcde}
03 Good Health and Well-being	26.87^{bcd}	27.45^{cde}	28.55^{cde}
04 Quality Education	27.11^{bcd}	31.01^{bcde}	29.06^{cde}
05 Gender Equality	22.70^{d}	22.91^{de}	24.68^{e}
06 Clean Water and Sanitation	38.28^{abc}	41.38^{ab}	37.42^{ab}
07 Affordable and Clean Energy	41.11^{a}	45.48^{a}	41.00^{a}
08 Decent Work and Economic Growth	37.47^{abcd}	25.80^{de}	31.94^{ab}
09 Industry	38.49^{abc}	38.51^{abc}	37.74^{ab}
10 Reduced Inequality	31.24^{abcd}	26.20^{de}	32.11^{abcde}
11 Sustainable Cities and Communities	30.16^{abcd}	34.85^{bcd}	31.06^{bcde}
12 Responsible Consumption and Production	36.68^{ab}	41.89^{ab}	38.01^{abc}
13 Climate Action	30.52^{abcd}	31.99^{bcde}	31.03^{bcde}
14 Life Below Water	31.85^{abcd}	32.59^{bcde}	32.26^{abcde}
15 Life on Land	34.03^{abcd}	33.05^{bcde}	34.78^{abcd}
16 Peace and Justice Strong Institutions	29.48^{cd}	26.10^{de}	27.49^{bcde}

Numbers in the same column followed by different letters are significantly different using SNK (P<0.05).

Alfred P Slone, Eunice Kennedy, among others. The Leverhulme Trust had the highest number of publications financed. In relative terms, philanthropical aid was higher in ASEAN and African countries (around 3.8% of the total) vs Latin America (2.4%).

Medicine and Physics & Astronomy were the two largest knowledge areas in most regions, except South and Central America and Africa, where Agriculture was also significant (Figure 8).

Three major clusters for collaboration were seen in South American collaboration (Figure 9). Brazil, Argentina, Chile, Uruguay and Colombia have the strongest links (in blue). There is a group of Spanish-speaking countries linked through Spain (green) and the third group of mainly English (or another language) speaking countries (red). Major topics studied are health, animal production and biodiversity (Figure 9). With ASEAN countries, there are 6 clusters with higher triangulation with countries outside the region. In Central America, there is a very clear division between health and biodiversity. Brazil tends to cite its own papers and shows high bibliographic coupling.

In south-south collaboration, more papers led to lower citation impact but higher in NSC (Table VI and Figure S4). A higher percentage of Brazilian authors as corresponding author led to a lower % of papers in Q1 journals, especially in NSC. % Industry also reduced the % papers in Gold Open Access journals.

DISCUSSION

Creating international research networks can cross borders and open supposedly sealed entities. These networks can create connections between disciplines, institutions and nations and create productive contacts between people who have little or nothing to do with each other. Proximity (both geographically and

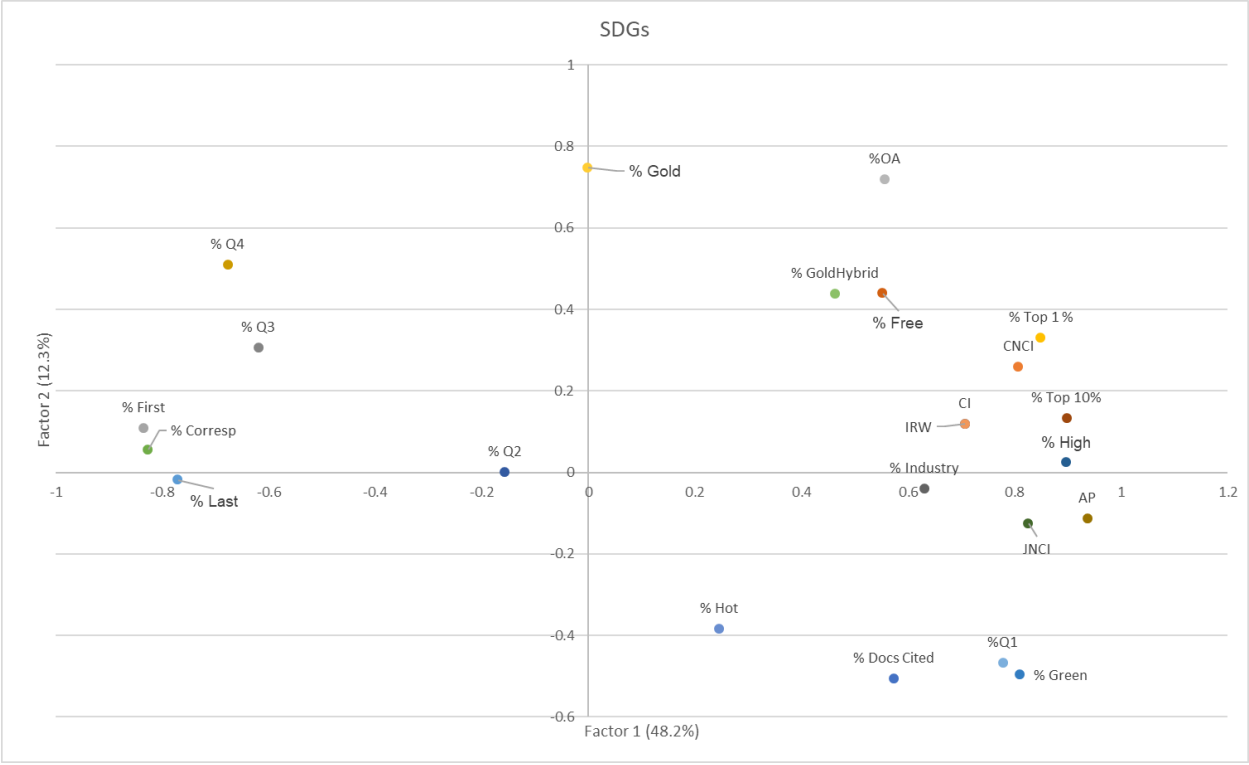


Figure 4. Overall Factor Analysis for papers published by Brazilian authors in South-South Collaboration (abbreviations in text).

scientifically) may mean that groups share the same information within the inner circle and uniform ways of thinking. At the same time, external influences generate new ideas (Buccieri et al. 2020).

The triangulation of SSC with NCS, as seen here, has been also seen with African studies (Boshoff 2010). This author emphasises that guidelines for successful North-South collaborations should be extended to include South-South collaborations that comprise highly unequal partners. The more people exchange ideas, the more the country benefits through increased interactions. The more open a country is to this exchange, the more scientifically important and influential it becomes (Kong et al. 2021). By internationalising research, scientists can access an additional funding source, not only financial but also laboratory equipment and consumables, access to the best research groups, join the "club", learn complementary skill sets, access to local knowledge, online data collection and access.

The "one size fits all" funding approach seems to reflect the conflation in much of the literature on research policy between academic and scientific research (Donovan 2005). Jeffrey (2003) argues that trends toward increasing interdisciplinary research reflect the complexity of modern problems and how funding bodies wish to see these problems tackled. This should be the basis for setting national priorities and attaining the goals. Themes relevant to several SDGs are either poorly researched or lack impact.

In the construction of partnerships, where the necessary structural conditions for developing the proposed activities are not yet sufficient, it is a ***sine qua non*** to include national and international institutions that can share the costs of projects. While SDG3 (Good health and

Table IV. Collaborations and Impact by SDG (A) and Country Group (B) in Collaboration with Brazilian Authors.

a

SDG	% Docs Cited	CNCI	% Top 1%	% Industry	% High	JNCI	%OA	% Gold	%Q1
01 No Poverty	82.63^{bc}	3.99^{b}	17.18^{a}	2.83^{bcd}	10.12^{ab}	1.65^{bcd}	77.82^{a}	37.77^{a}	59.89^{a}
02 Zero Hunger	89.18^{ab}	2.65^{bc}	8.11^{b}	1.98^{bcd}	7.71^{bc}	1.94^{ab}	55.68^{cd}	27.33^{bcd}	56.58^{a}
03 Good Health and Well-being	89.58^{a}	3.95^{b}	7.54^{bc}	8.78^{a}	7.35^{bc}	1.94^{ab}	64.60^{bc}	26.87^{bcd}	54.11^{a}
04 Quality Education	76.49^{d}	2.50^{bc}	8.40^{b}	1.36^{cd}	5.53^{c}	1.34^{de}	65.77^{bc}	32.89^{ab}	45.62^{b}
05 Gender Equality	89.05^{ab}	7.57^{a}	14.92^{a}	7.74^{a}	12.30^{a}	2.10^{a}	71.17^{ab}	27.58^{bcd}	57.13^{a}
06 Clean Water and Sanitation	90.73^{a}	1.76^{c}	3.68^{bc}	2.23^{bcd}	5.31^{c}	1.85^{ab}	40.33^{ef}	18.66^{efg}	54.90^{a}
07 Affordable and Clean Energy	88.46^{ab}	1.58^{bc}	2.15^{c}	3.45^{bcd}	3.94^{cd}	1.31^{e}	35.68^{f}	14.41^{g}	59.38^{a}
08 Decent Work and Economic Growth	81.46^{cd}	2.54^{bc}	8.54^{b}	5.19^{b}	7.68^{bc}	1.43^{cde}	45.34^{ef}	15.12^{g}	58.62^{a}
09 Industry	80.65^{cd}	1.61^{c}	3.54^{bc}	3.20^{bcd}	4.15^{cd}	1.30^{e}	44.18^{ef}	14.95^{g}	53.72^{a}
10 Reduced Inequality	76.59^{d}	2.50^{bc}	7.09^{bc}	3.49^{bcd}	5.44^{c}	1.31^{e}	70.76^{ab}	31.56^{bc}	40.72^{bc}
11 Sustainable Cities and Communities	86.74	2.66^{bc}	5.15^{bc}	3.18^{bcd}	5.92^{c}	1.71^{bc}	48.41^{de}	22.04^{defg}	57.44^{a}
12 Responsible Consumption and Production	89.01^{ab}	1.72^{c}	3.15^{bc}	3.84^{bcd}	5.18^{c}	1.64^{bcd}	41.37^{ef}	17.12^{fg}	57.73^{a}
13 Climate Action	88.73^{ab}	2.59^{bc}	6.41^{bc}	4.98^{bc}	7.17^{bc}	1.75^{bc}	56.21^{cd}	23.74^{def}	62.35^{a}
14 Life Below Water	89.69^{a}	2.82^{bc}	7.03^{bc}	2.62^{bcd}	7.44^{bc}	1.80^{ab}	56.06^{cd}	25.01^{bde}	56.92^{a}
15 Life on Land	88.63^{ab}	2.80^{bc}	7.56^{bc}	2.91^{bcd}	7.33^{bc}	1.72^{bc}	56.60^{cd}	23.99^{def}	56.18^{a}
16 Peace and Justice Strong Institutions	67.37^{e}	2.03^{c}	7.51^{bc}	0.44^{d}	1.69^{d}	1.41^{cde}	66.80^{bc}	20.58^{defg}	37.16^{c}

b

Country	% Docs Cited	CNCI	% Top 1%	% Industry	JNCI	%High	%OA	% Gold	%Q1
Africa	87.28^{a}	3.62^{a}	10.06^{bc}	5.34^{a}	1.96^{a}	8.29^{bc}	67.39^{a}	23.17^{bc}	62.23^{a}
Arab	89.67^{a}	4.16^{a}	13.71^{a}	6.50^{a}	2.05^{a}	11.34^{a}	63.98^{ab}	26.43^{bc}	64.06^{a}
Asean	90.34^{a}	3.86^{a}	11.44^{ab}	4.69^{ab}	2.04^{a}	10.38^{ab}	66.97^{a}	22.60^{bc}	66.76^{a}
Asia	88.96^{a}	3.11^{a}	9.01^{bc}	4.52^{ab}	1.90^{a}	7.76^{c}	59.46^{ab}	22.89^{bc}	64.64^{a}
BRICS	88.75^{a}	3.26^{a}	9.44^{bc}	4.48^{ab}	1.86^{a}	8.41^{bc}	58.41^{b}	20.81^{cd}	65.10^{a}
Brazil with world	77.27^{b}	0.88^{b}	0.93^{d}	0.76^{c}	1.02^{d}	0.96^{e}	47.90^{c}	33.63^{a}	34.50^{d}
Caribbean	79.54^{b}	3.46^{a}	6.48^{c}	2.11^{c}	1.40^{c}	6.61^{c}	46.16^{c}	20.79^{cd}	41.24^{c}
Central America	85.49^{a}	3.08^{a}	7.97^{cd}	4.49^{ab}	1.64^{b}	7.00^{c}	55.98^{b}	22.45^{bc}	49.91^{b}
South America	81.40^{b}	1.87^{b}	3.67^{d}	2.42^{bc}	1.35^{c}	3.27^{d}	56.12^{b}	27.91^{b}	48.92^{b}
World with World	78.18^{b}	1.00^{b}	1.01^{d}	1.09^{c}	1.14^{d}	1.10^{e}	38.12^{d}	16.58^{d}	45.42^{bc}

Numbers in the same column followed by different letters are significantly different using SNK (P<0.05).

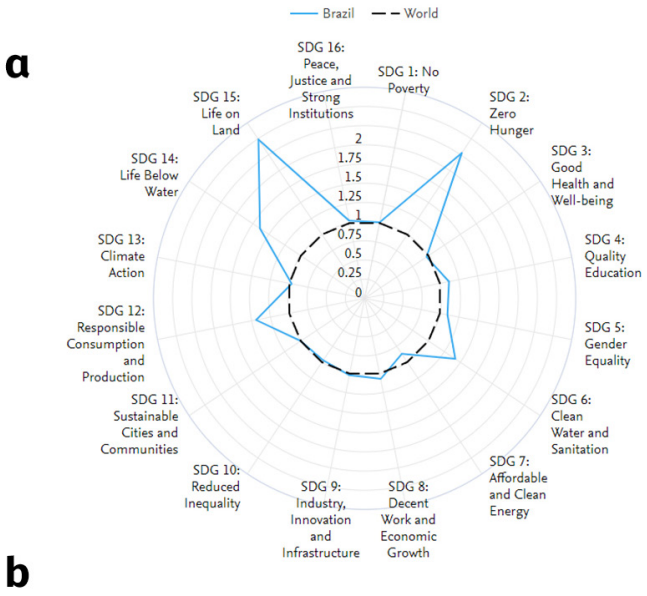


Figure 5. Relative Activity Chart (a) (SciVal 2021-2022)[2] and Web of Science Documents (b) (InCites®) for Brazil (2012-2022) by Sustainable Development Goal.

well-being) was found to have a higher share of synergies with other SDGs in most of the countries and the world population (Pradhan et al. 2017) the concentration of Brazilian production (50%) on this SDG may reflect the need for directed actions on other important SDGs. Interdisciplinary teams are important for solving complex problems (Mosquera 2020) such as SDGs. Few research calls in Brazil are directly linked to SDG challenges or benchmarked through goal attainment. Several authors call for new frameworks for strengthening stakeholder participation and structuring knowledge for policy-makers (Yillia 2016, Maes et al. 2019, McCollum et al. 2018).

Table V. Number of publications funded by private entities, philanthropical and the European community.

	BRICS	South America	Asia	ASEAN	Africa	Carib & Central America	Arab
Private	1193	644	1797	709	1394	1439	566
Europe	9167	8842	9155	5367	4494	4291	6600
Phil	3665	3122	3428	2912	2176	2168	3238

The training of Brazilian human resources must be an essential component of cooperation. The search for partners must consider their areas of excellence and the existence of common research topics. Scientific and technical human capital (S&T human capital) is the sum of scientific, technical and social knowledge, skills and resources embodied in a particular individual (Bozeman et al. 2001). It includes human capital endowments, such as formal

[2] The Relative Activity Index is defined as the share of a Country's Scholarly Output in a SDG relative to the worldwide share of Scholarly Output in that same SDG.

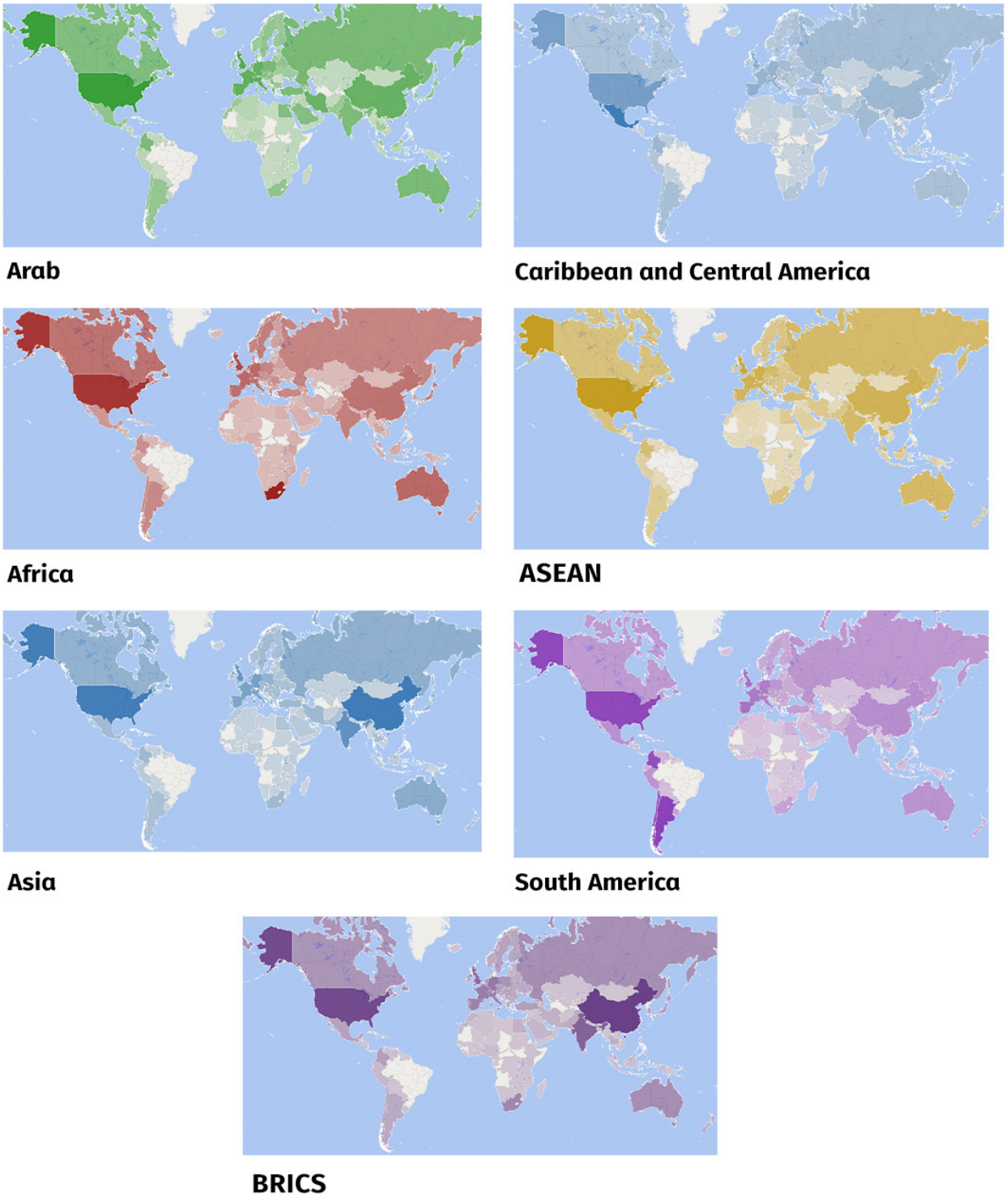


Figure 6. Heat map for number of documents in collaboration by countries that publish with Brazil together with global south country groups.

Table VI. Significant paths for South-South (a) and North-South (b) Collaborations with Brazilian scientists.

Path			Estimate	SE	t Value	Pr > |t|
South-South Collaboration						
WoS	to	%Industry	-0.26	0.07	-4.03	<.0001
WoS	to	%Corresp	0.34	0.06	5.49	<.0001
WoS	to	Citation_Impact	-0.44	0.11	-3.93	<.0001
%Industry	to	Citation_Impact	0.56	0.04	12.60	<.0001
%Industry	to	%Docs_Cited	0.44	0.06	7.74	<.0001
%Industry	to	%Q1	0.19	0.04	4.70	<.0001
%Industry	to	%Gold	-0.43	0.06	-7.52	<.0001
Times_Cited	to	Citation_Impact	0.25	0.11	2.24	0.03
%Corresp	to	%Q1	-0.09	0.04	-2.13	0.03
%Q1	to	PTop10%	0.71	0.03	20.31	<.0001
%Q1	to	Citation_Impact	0.24	0.05	4.96	<.0001
%Q1	To/from	%OA	0.79	0.03	31.03	<.0001
%Q1	To/from	%Hybrid	0.56	0.04	12.53	<.0001
%Q1	to	%Hot	0.39	0.06	6.51	<.0001
%Q1	to	%High	0.58	0.05	12.36	<.0001
%High	to	CNCI	0.15	0.01	11.72	<.0001
%Hot	to	CNCI	0.03	0.01	3.80	0.00
%Q1	to	CNCI	-0.05	0.01	-3.96	<.0001
%Hybrid	to	CNCI	0.12	0.01	10.49	<.0001
Citation_Impact	to	CNCI	0.95	0.01	127.60	<.0001
%Top10%	to	CNCI	-0.04	0.01	-4.45	<.0001
North South Collaboration						
WoS	to	%Industry	-0.16	0.07	-2.45	0.01
WoS	to	Citation_Impact	0.22	0.16	1.38	0.17
WoS	to	%Corresp	0.29	0.06	4.78	<.0001
%Industry	to	Citation_Impact	0.62	0.04	15.46	<.0001
%Industry	to	%Docs_Cited	0.33	0.06	5.39	<.0001
%Industry	to	%Q1	0.06	0.04	1.65	0.10
%Industry	to	%Gold	-0.43	0.06	-7.83	<.0001
Times_Cited	to	Citation_Impact	-0.41	0.16	-2.55	0.01
%Corresp	to	%Q1	-0.15	0.04	-4.05	<.0001
%Q1	to	PTo%10%	0.36	0.06	6.04	<.0001
%Q1	to	Citation_Impact	0.09	0.05	1.88	0.06

Table VI. Continuation.

Path			Estimate	SE	t Value	Pr > |t|
North South Collaboration						
%Q1	To/from	%OA	0.80	0.02	36.96	<.0001
%Q1	To/from	%Hybrid	0.76	0.03	27.78	<.0001
%Q1	to	%Hot	0.22	0.07	3.32	0.00
%Q1	to	%High	0.19	0.07	2.82	0.00
%High	to	CNCI	0.18	0.01	13.25	<.0001
%Hot	to	CNCI	0.06	0.01	7.86	<.0001
%Q1	to	CNCI	-0.05	0.01	-4.02	<.0001
%Hybrid	to	CNCI	0.09	0.01	7.50	<.0001
Citation_Impact	to	CNCI	0.97	0.00	195.80	<.0001
%Top10%	to	CNCI	-0.07	0.01	-8.43	<.0001

education and training, and social relations and network ties that bind scientists and science users together as a knowledge value collective (Bozeman & Corley 2004).

In asymmetric SSC relationships, where excellence may be mainly in Brazil, the partnership should go beyond the transfer of knowledge and other aspects of solidary cooperation. This type of partnership should make clear the scientific and technological stimuli for Brazil, in addition to the benefits arising from the coexistence of international students and researchers with Brazilians.

Sachs et al. (2019) introduce six SDG transformations as modular building blocks of SDG achievement: (1) education, gender and inequality; (2) health, well-being and demography; (3) energy decarbonisation and sustainable industry; (4) sustainable food, land, water and oceans; (5) sustainable cities and communities; and (6) digital revolution for sustainable development. The relationship between SDGs is important, as some are interdependent and other have conflicting results. For example, it may be difficult to balance balancing economic development, environmental sustainability, and social inclusion for human well-being (Ibisch et al. 2016). According to Pradhan et al. (2017), SDG 1 (No poverty) has a synergetic (progress in one goal favours progress in another) relationship with most of the other goals. SDGs 8 (Decent work and economic growth), 9 (Industry, innovation, and infrastructure), 12 (Responsible consumption and production), and 15 (Life on land) on the other hand, are associated with a high fraction of trade-offs across SDGs (progress in one goal hinders progress in another).

Leal Filho et al. (2022) note that five SDGs have deteriorated since 2015: SDG2, SDG11, SDG13, SDG15, and SDG16, while SDG3, SDG7, SDG9, SDG14, and SDG17 have shown substantial progress. SDGs 1, 8, 10, 12, and 16 in Brazilian collaboration are less well developed. According to Swain (2018) and Bali-Swain & Yang-Wallentin (2020), developing countries should focus on their economic and social factors, even though environmental policies remain significant for sustainable development. The authors highlight that developed countries should focus on social and environmental factors. This difference in policy is also the underlying thread seen in the differences between NSC and SSC. In the present paper, we see different research profiles depending on partnerships.

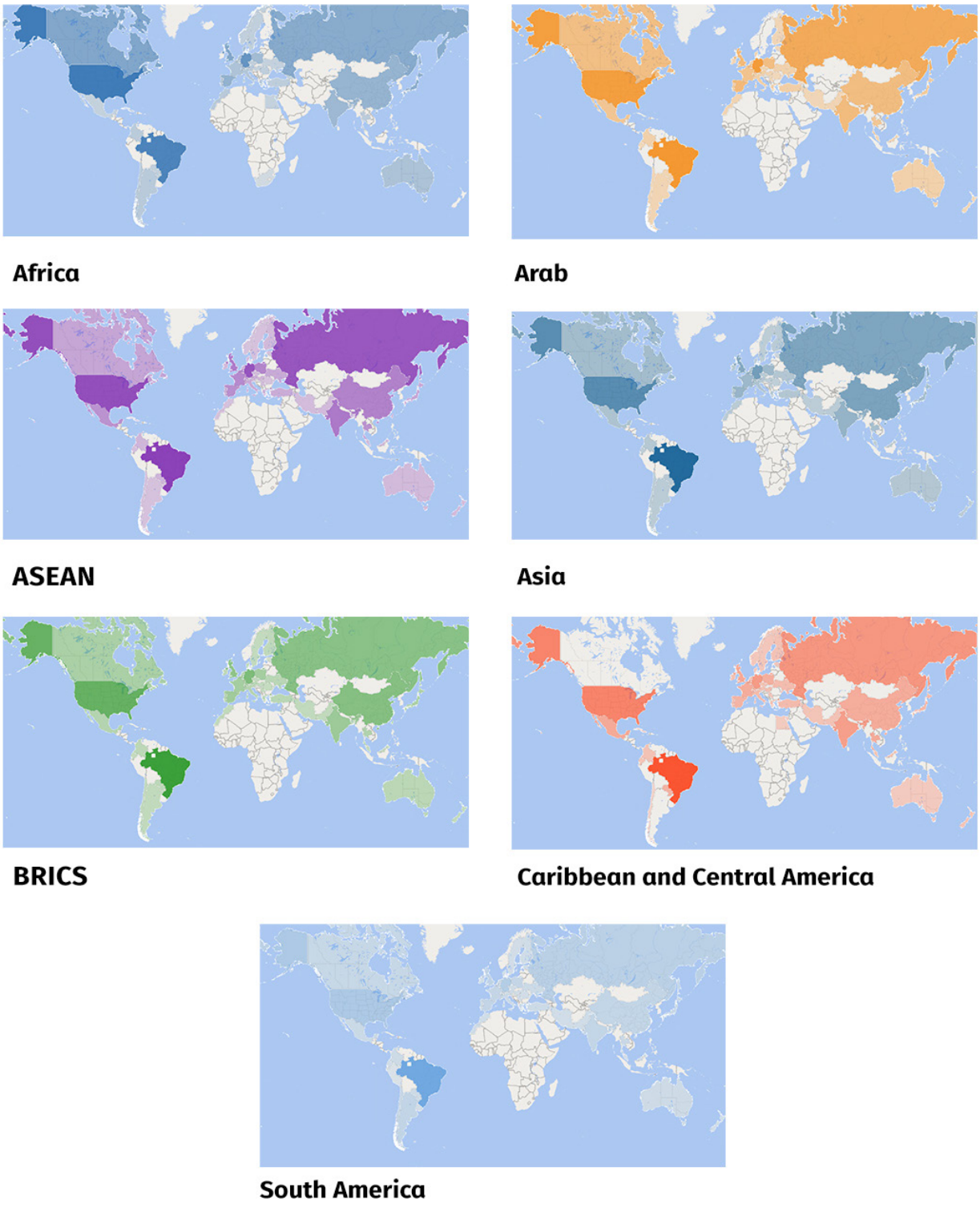


Figure 7. Heat map for countries funding Brazilian research with different global south country groups.

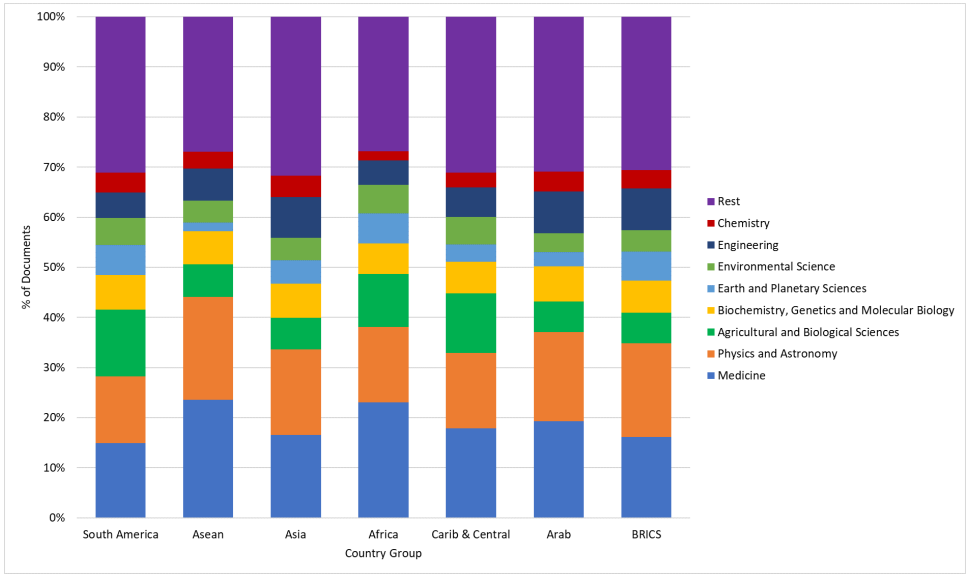


Figure 8. Areas of research receiving non-Brazilian financing in collaboration with Global South country groups.

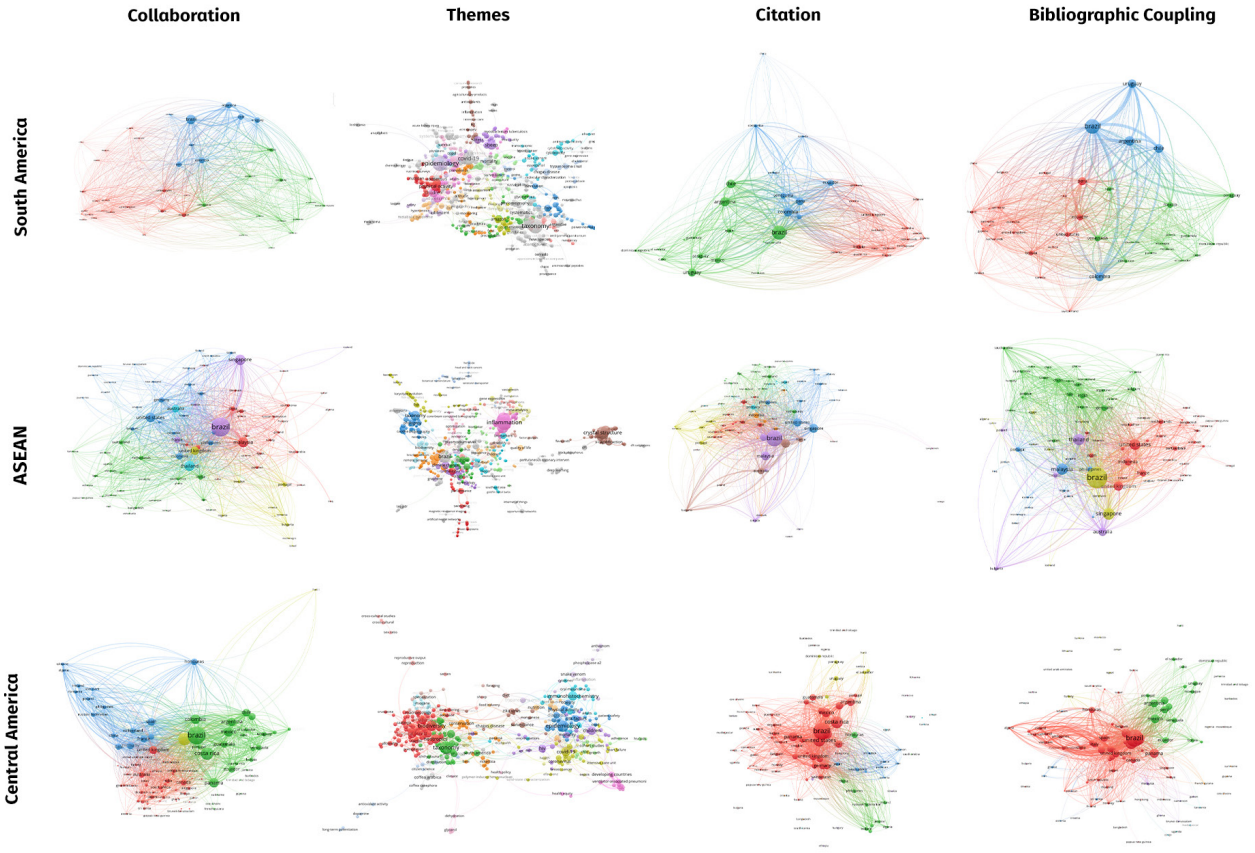
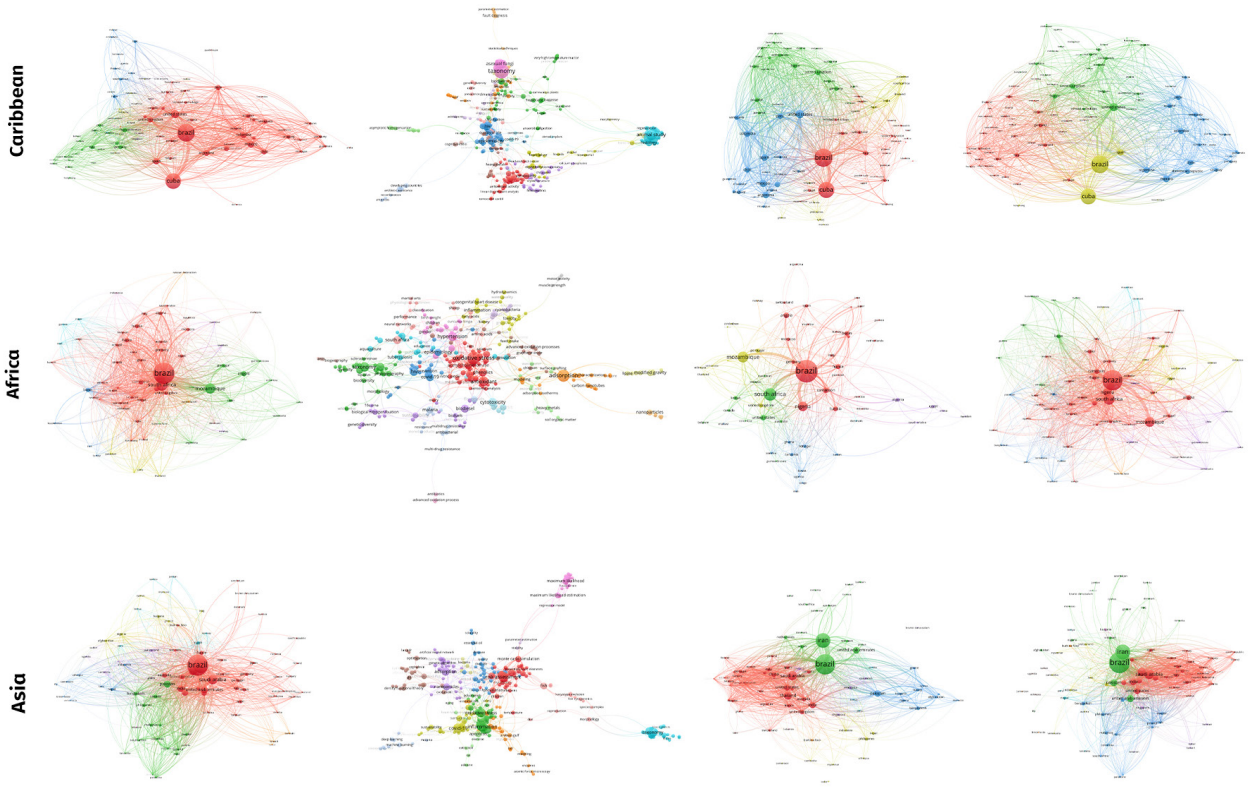


Figure 9. Bibliographic mapping networks of Brazilian publications with different south-south country groups: Column a) Collaboration countries; b) Themes; c) Citation countries; d) Bibliographic coupling countries.



According to Cooke (2005), open innovation on a global basis to overcome inherent knowledge asymmetries and overturn the imbalance in an evolutionary process over time. Kim (2006) states that the symmetrical type of international research collaboration has intensified while the dominance of the asymmetrical type has declined. Based on the number of participating countries, we can see that multilateral papers written by researchers from three or more countries have increased considerably during the last two decades, as seen here. Research shows that knowledge asymmetries can be overcome by tapping into the regional knowledge capabilities and systemic innovation strengths of accomplished regional and local clusters. These regional knowledge capabilities help metamorphose macro-processes operating through globalisation (Cooke 2005). Luo et al. (2013) show that international partnerships often encounter barriers such as resource, capacity, political and cultural differences, which affect the motivations, balance of benefits, regulation of research, and ultimately, outcomes of these programs. Results here show that SSC can be beneficial to Brazilian science. There is the benefit of opening gateways to other international partnerships, network creation and emphasis on regional priorities.

South-South Cooperation is one of the aspects of this mission as it is characterised as a scientific collaboration between Brazil and other developing countries in Latin America, Africa and Asia. It is understood that this type of partnership enriches all the actors involved, not only in the academic-scientific aspect but also in the exchange of cultural, ethical and social values. Furthermore, we recognise that expanding scientific knowledge is more than ever a global undertaking, which must go beyond the countries of the North, recognising that there are different problems in different societies and

that, to solve them, the participation of different perspectives is essential and complementary. Contrary to Molosi-France & Makoni (2020), SSC can be equally impactful as NSC. This may be because the selection of partners was better with SSC or because of the triangulation that exists with Global North Countries. 54% international collaboration of Brazil is NSC and 46% SSC.

CONCLUSIONS

SDGs can be useful in constructing a research and financing agenda for Brazilian research in scientific collaboration and for the solution of problems. Collaboration priorities can vary by Brazilian region. Brazil South-South collaboration in published documents shows a higher impact than NSC in some areas. Brazilian SSC shows triangulation with countries in the Global North and depends on language, financing and region. As such, the choice of partnerships is important to increase the impact of the research produced. The search for partners must consider their areas of excellence and the existence of common research topics. In asymmetric relationships, where excellence is mainly in Brazil, the partnership should go beyond knowledge transfer and other aspects of solidary cooperation. This type of partnership should make clear the scientific and technological stimuli for Brazil, in addition to the benefits arising from the coexistence of international students and researchers with Brazilians.

Acknowledgments

The authors acknowledge the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brazil; and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil. The authors declare no conflict of interest.

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SUPPLEMENTARY MATERIAL

Table SI-SV.
Figure S1-S4.

How to cite
MCMANUS C, NEVES AAB, SCHLEICHER RT, CASTRO HCO, PIMENTEL F, PIMENTEL D & FINAN TJ. 2023. Brazilian South-South Scientific Collaboration and The Sustainable Development Goals. An Acad Bras Cienc 95: e20230492. DOI 10.1590/0001-3765202320230492.

Manuscript received on April 30, 2023;
accepted for publication on July 30, 2023

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