DSI DATA SCIENCE AND INFORMETRICS
VOL.3, NO.3, AUG. 2023

RESEARCH ARTICLE

Science collaboration in West Africa after the first regional STI policy (2011–2020)

Eustache Mêgnigbêto*

a. University of Antwerp, Faculty of Social Sciences, Antwerp, Belgium
b. Bureau d´études et de recherches en science de l´information, Cotonou, Benin

ABSTRACT
The scientific publications of the 15 West African countries published from 2011 to 2020 were analysed. The co-authorship, the total publications per year, the collaboration rate, the relative specialisation index, and the intraregional production were analysed. It comes out that the region produces more than one hundred thousand papers in ten years, which means more than ten thousand per year, tripling its performance as compared with the previous decade. The number of co-authors per paper increases and rises from 4.6 to 6.4. The international collaboration rate is 58%, suggesting that the region's publishing activity depends more on abroad, even though differences were registered at individual country level: some countries multiply by more than 10 their production as compared to the previous decade. The intraregional collaboration is still low (around 5%), meaning that the region's countries do not collaborate with each other and prefer abroad. As far as fields of science are concerned, it appears that the domestic papers perform better in Humanities and Social sciences, whereas the internationally co-authored papers perform better in Natural sciences and Engineering and technology and lesser in Agricultural sciences and Medical and health sciences.

KEYWORDS
Research collaboration; Scientific publishing; Research evaluation; West Africa; Africa

1 Introduction

Studying collaboration in science allows knowing how research actors (for example, authors, groups, institutions and countries; cf. Katz & Martin, 1997, p. 9) organise to produce and share knowledge; it is so important that specific methods and techniques were developed (e.g., author co-citation analysis introduced by White & Griffith, 1981) and indicators designed (Bordons & Gomez, 2000; Katz & Martin, 1997). Around the world, various studies have dealt with research collaboration at author, group, institution, country, region, or international level (Adams, 2012, 2013; Adams et al., 2010, 2014; Glänzel, 2000, 2001; Leydesdorff et al., 2013; Wagner et al., 2015). However, collaboration in science is a complex social phenomenon (Glänzel, 2001; Glänzel & Schubert, 2005; Katz & Martin, 1997) and, hence, is subject to change (Ossenblok et al., 2014, p. 883); so, there is a need to observe it continuously and report any change in its patterns.

* Corresponding Author: eustachem@gmail.com / eustache.megnigbeto@uantwerpen.be

Science in Africa is not studied as much as in Western countries, even though an interest, as measured by the number of scientific publications in the field, is being registered as compared to several decades ago (Africa Union Commission, 2014; Confraria & Godinho, 2015; Mêgnigbêto, 2021). For the production and use of relevant indicators in support of knowledge management, the African Union has taken some initiatives that result, for example, in the publication of the African Innovation Outlook reports of which the two most recent were released in 2014 and 2019 (African Union Development Agency, 2019; NEPAD Planning and Coordinating Agency, 2014). West African science in particular were studied both at the regional and national level even though individual countries are not covered equally (Essegbey et al., 2015; Mêgnigbêto, 2012, 2013a, 2013b, 2013c, 2016; UNESCO, 2015, 2021). Many of these studies were published several years ago and had intervened before the execution of the first regional science, technology, and innovation policy, the ECOPOST. The present paper has the objective to deal with international collaboration in West African science after the ECOPOST both at the national and regional level; particularly, it aims to: i) draw the landscape of scientific publication in West Africa over the period 2011-2020; ii) update science collaboration indicators in West Africa, and iii) compare West Africa profile over the period 2011-2020 to the one over the period 2011-2020, in terms of research collaboration. We formulate the following research questions: 1) How do African-based research actors collaborate? 2) How does research collaboration in West Africa evolve?

2 Background on STI policy in West Africa

The 15 West African states[1] in 1975 formed the Economic Community of the West African States (ECOWAS), a regional economic organisation. Scientific activities in the area date back to the colonial period, when colonial powers were interested in the exploitation of the natural resources their colonies were endowed with (Commission de la CEDEAO, 2012, p. 17; UNESCO, 1986, p. 14-15). After their independence, the majority of the West African countries incorporated into their socio-economic development plans parts about scientific activities; therefore, no separate policy on science, technology, and innovation was formulated at any country level. With the efforts of UNESCO (cf. Davis, 1983) in training, advising and technical assistance, either directly with countries or regional organisations, African countries have started formulating science, technology and innovation documents. Today, a few numbers of ECOWAS countries have adopted such a policy document. At each country level, however, policymakers acknowledge the role of science, technology and innovation in achieving national development goals and transforming economic growth (Gurib-Fak & Signé, 2022; Sooryamoorthy, 2020; UNESCO, 1974, p. 27, 1986, p. 12); as an illustration, national development plans always refer to science, technology and innovation as a means to face development challenges[2].

1 The members are in the alphabetic order: Benin, Burkina Faso, Cape Verde, Cote d´Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo (African Union Commission & New Zealand Ministry of Foreign Affairs and Trade, 2014; Resolution on the division of Africa into five regions, 1976). The countries list was updated on changes; the last version is provided by the African Union Commission (2020).

2 See for example national development plans: Benin (Bénin. Ministère d´Etat chargé du plan et du développement, 2018), Burkina Faso (Burkina Faso. Gouvernement du Burkina Faso, 2021), Cape Verde (Cabo Verde. Governo de Cabo Verde, 2017), Cote d´Ivoire (Cote d´Ivoire. Ministère du plan et du développement, 2016), The Gambia (The Gambia. Government of The Gambia, 2018), Ghana (Ghana. National development planning commission, 2021), Guinea (Guinée. Ministère du Plan et de la Coopération Internationale, 2016), Guinea Bissau (Guinea Bissau. Gouvernement de Guinée Bissau, 2015), Liberia (Liberia. Government of Liberia, 2018), Mali (Mali. Gouvernement du Mali, 2019), Niger (Niger. Ministère du plan, 2017), Nigeria (Nigeria. Federal Ministry of Finance, Budget and National Planning, 2021), Senegal (Senegal. Gouvernement du Sénégal, 2018), Sierra Leone (Sierra Leone. Government of Sierra Leone, 2018) and Togo (Togo. Gouvernement du Togo, 2018).

In 2007, the ECOWAS Commission created within the Office of the Commissioner Human Development and Gender, a Department for Education, Culture, Science and Technology with a mandate to promote science, technology and innovation for regional integration, economic development, overall poverty reduction, and social emancipation of the people of West Africa. The ECOWAS vision 2020 (ECOWAS Commission, 2011) reaffirms the necessity to promote active participation of the academic community in all issues relating to the integration process. The ECOWAS Policy on Science and Technology (ECOPOST), a five-year document, and its action plan (Commission de la CEDEAO, 2012) were adopted by the Authority of Heads of State and Government on 29 June 2012. The policy document targets to help Member States to master all science fields required for the emergence of a scientific community able to compete and to exchange with the best research teams worldwide. It addresses 12 thematic areas.[3] Other policy documents at regional (ECOWAS Commission, 2011) or continental (Africa Union Commission, 2005, 2014, 2015; Organisation of African Unity, 1980) recognized the role and the importance of science in development. Identified hindrances to the development of STI within the region are related to capacity for STI, human resource development, promoting and funding research and development, and STI policy and measurements.

Table 1 Status of West African countries regarding the existence of an explicit STI policy (adapted from Mêgnigbêto, 2016)

Country	Existence of a STI policy	Year of the adoption of the first STI policy	Year of the adoption of the current STI policy	Number of STI policies yet formulated
Benin	Yes	2006	2015	2
Burkina Faso	Yes	1995	2012	2
Cape Verde	No	–	–	–
Cote d´Ivoire	No	–	–	–
Gambia (The)	Yes	–	2013	1
Ghana	Yes	2000	2010	2
Guinea	No	–	–	–
Guinea Bissau	No	–	–	–
Liberia	No	–	–	–
Mali	Yes	2009	–	–
Niger	Yes	–	2013	1
Nigeria	Yes	–	2011	1
Senegal	No	–	–	–
Sierra Leone	No	–	–	–
Togo	Yes	–	2014	1

3 There are : (a) scientific research, innovation and technological development; (b) support for education and training; (c) higher education; (d) scientific culture; (e) enabling environment for scientific creativity; (f) regional and international cooperation; (g) capacity building; (h) science and technology and private sector involvement; (i) information on S&T: data, statistics and indicators; (j) gender, science and technology; (k) E-governance and Internet massification; and (l) transfer of technology and technology watch (United Nations Economic Commission for Africa, 2014, p. 79)

3 Literature review

A number of papers published in the last decade dealt with research collaboration in Africa. Toivanen and Ponomariov (2011a) studied the whole of Africa's research collaboration pattern; they distinguished three separate "scientific regions": the Northern (6 countries), the Western (23 countries), and the Southern-Eastern (25 countries). They reported an increasing trend in the number of authors who contributed to an article from 4.1 in 2005 to 4.5 in 2009 and underlined the concentration of the growth in the group of papers with 5 or more authors, illustrating the importance of collaboration in African science. The same trend in co-authorship was noticed by Mêgnigbêto (2013a, 2016) while studying the scientific output of the West African region and Mêgnigbêto (2012, 2013c) within the Beninese, Ghanaian and Senegalese scientific production. Collaboration between African regions or countries is too low, indicating "the absence of regional integration in the African innovation systems" (Mêgnigbêto, 2013a, 2016; Onyancha & Maluleka, 2011; Toivanen & Ponomariov, 2011a). African regions were weakly connected; a few countries served as major research hubs: Kenya, Tanzania, Uganda, South Africa, Egypt, Nigeria and Cameroon (Toivanen & Ponomariov, 2011a). The Northern region has no direct links neither with the Western nor with the Southern-Eastern ones (Toivanen & Ponomariov, 2011a). In West Africa, Mêgnigbêto (2013a) identified a French-speaking group (including Senegal and Cote d'Ivoire) that has strong ties with African French-speaking countries only, a bilingual group (including Benin and Burkina Faso) that has strong relations with both English and French-speaking countries and an English speaking group made up with Nigeria, Ghana, Gambia and Mali. The international collaboration rate is increasing; it has risen very significantly from 30% in the early 1990's up to 50% starting from 2000 (Onyancha & Maluleka, 2011). The profiles of African countries regarding international cooperation showed significant differences, however, ranging from 29% to 87%. The main partners of both African regions and countries are European and North American countries, especially the United States of America, the United Kingdom, France and Germany, in this order. African countries have strong ties with their former European colonisers like France and the United Kingdom (Mêgnigbêto, 2013a), illustrating the continuing legacy of colonisation. New partners are being registered: China, Russia, Brazil, and India's shares of African science are growing (Mêgnigbêto, 2021; Muchie & Patra, 2020). As far as intra-African collaboration is concerned, language, culture and geographical close-up were identified as drivers (Mêgnigbêto, 2013a, 2016; Onyancha & Maluleka, 2011). South Africa is the main African partner country for many Africa Member States. In the West African case particularly, the international collaboration rate at both regional and individual countries levels is high (around or more than 50%), denoting a high independence to abroad. On the other hand, collaboration between countries within the region is still low (Essegbey et al., 2015; Mêgnigbêto, 2013a, 2016, 2021; UNESCO, 2015, 2021). Nigeria dominates the regional output by producing, on its own, more than the 14 other countries (Mêgnigbêto, 2013, 2021); it is also the first source country partner of the region's science partner countries (Mêgnigbêto, 2013, 2021).

To summarise, a few countries dominate the continent's scientific output; they are South Africa, Kenya, Nigeria, Cameroon and Tanzania, Morocco and Egypt. These countries also drive collaboration links; therefore, they are the backbone of the scientific collaboration network in Africa and connect African regions and Africa to the World. Language, culture, colo-

nial ties and geographical close-up are criteria for collaboration; hence, the main African countries' common partners are former colonial powers, namely France and the United Kingdom; however, the USA follows as the third common partner country even though it has no former colony on the Continent. Cooperation between developing countries is weak, and so is cooperation between African countries. Developed countries are the major non-African partners of African countries, and countries with the same region collaborate more than they do with other regions' countries.

4 Methods and data

In July 2021, we searched the Web of Science for all documents published between 2011 and 2020 included, with at least one author with a home address in any of the 15 countries of West Africa. The following six databases were selected from the Web of Science Core Collection: Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Conference Proceedings Citation Index-Science (CPCI-S), Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH), Emerging Sources Citation Index (ESCI)[4]. The search expression were (cu=benin or cu=burkina faso or cu=cote ivoire or cu=cape verde or cu=gambia or cu=ghana or cu=guinea or cu=guinea bissau or cu=Liberia or cu=mali or cu=niger or cu=nigeria or cu=senegal or cu=sierra leone or cu=togo) and py=2011-2020. The resulting records (around 106,027) were downloaded; a PHP script was coded to import data into a suitable format to be treated with ISIS technology (de Smet, 2009b, 2009a). As Mêgnigbêto (2015, 2016, p. 214) noticed, this search expression also selected data of countries like Equatorial Guinea and Papua New Guinea due to the presence of the term "cu=guinea". Because these two countries are not members of the ECOWAS, records related to them with no West African addresses (4,481) were selected and deleted from our local database. Finally, 101,546 records were considered, treated and analysed. The functions of the database management software are used to execute the search and print data into files for further analysis.

5 Results

5.1 Co–authorship

The number of authors per paper varies from 1 to 3,445, with a mean of 6.49 authors per paper. One fourth of the publications has at most 3 authors, one half at most 4 authors and three fourths at most 7 authors; 11% of the papers have only one author, so 89% have at least two authors. The number of papers with 3 authors has the higher share (16%). Beyond three authors, the share of papers decreases exponentially and tends toward 0, showing how skewed is the distribution of authors within the studied set. Table 2 presents the evolution of the number of authors per paper (and in reverse, the number of papers per author) in West African scientific publishing from 2011 to 2020. The number of authors per paper takes its lowest value (4.5) in 2013 and the highest one (7.25) in 2019. Over the period, the output in-

4 While these six databases were selected in the *Advanced search* options, the *Analyse results* page displayed results from the following databases: Science Citation Index Expanded, Conference Proceedings Citation Index–Social Sciences and Humanities, Book Citation Index– Science, Emerging Sources Citation Index, Arts and Humanities Citation Index, Current Chemical Reactions, Social Sciences Citation Index, Index Chemicus, Book Citation Index–Social Sciences and Humanities, Conference Proceedings Citation Index–Science.

creased with a linear trend. In comparison with the same statistics for the previous decade recorded by Mêgnigbêto (2013a, 2016), the number of papers per author diminishes from 0.21 to 0.15, and the number of authors per paper rises from 4.82 to 6.49, indicating the increasing importance of collaboration in the region's science following the global trends (Ossenblok et al., 2012, 2014).

Table 2 Co-authorships statistics in the West African science (2011-2020)

Year	# authors	# papers	author / paper	paper / author
2011	26,911	5,203	5.17	0.19
2012	30,272	5,273	5.74	0.17
2013	26,370	5,801	4.55	0.22
2014	39,048	6,423	6.08	0.16
2015	61,682	9,804	6.29	0.16
2016	73,271	10,569	6.93	0.14
2017	86,711	12,582	6.89	0.15
2018	99,862	13,701	7.29	0.14
2019	113,059	15,562	7.27	0.14
2020	101,718	16,628	6.12	0.16
Total	658,904	101,546	6.49	0.15

5.2 Volume of production and international collaboration rate

Over the period of study (2011-2020), the West African region produced a little more than one hundred thousand (101,546) papers. Figure 1 reveals that the region's output increased and is best fitted by a linear function of which equation is y = 1,415.7t + 2,368.3, where y is the number of papers and t the period of time (t = 1 in 2011 and R2 = 0.97). This means that each year of the considered period, West Africa is expected to produce 1,416 additional papers as compared to the previous year. The curve shows an increasing growth in the regional production through the years; however, the speed of growth is not the same. From 2001 to 2014, it was slow and intensified from 2014 to 2018 before decreasing from 2018 to 2020. The move seems sudden from 2014 to 2015. From the beginning of the period to its end, West Africa tripled its scientific output, from 5,203 in 2011 to 16,628 in 2020. As compared to the previous decade (Mêgnigbêto, 2013a, see 2016), the production over 2011-2020 is 3.18 times the one of the period 2001-2010.

Over the total output, 58,892 records bear at least one non-West African country address, resulting in an overall collaboration rate of 58%. In other words, more than half the regional output was shared with abroad. This rate, however, varies both over the years (it starts at 51% the first year and reaches 60% at the end of the period) and in countries; indeed, at the national level, it takes its lowest value with Nigeria (47.17%) and its highest one with Guinea Bissau (99.24%). Excepting Nigeria, four countries have an international collaboration rate lower than 80% (Ghana 67.79%; Cote d'Ivoire 76.71%, Senegal 77.70% and Togo 77.90%), two an international collaboration rate comprised between 80% and 90% (Benin 81.91 and Burkina Faso 86.84%); the remaining eight have a rate higher than 90% (cf. Table 4). Com-

pared with the previous decade, the international collaboration rate has increased from 51% to 58%.

In summary, West African science production is growing at a linear trend over the decade, so that at the end of the period, the region could triple its production; the international collaboration rate increases from 51% to 58%.

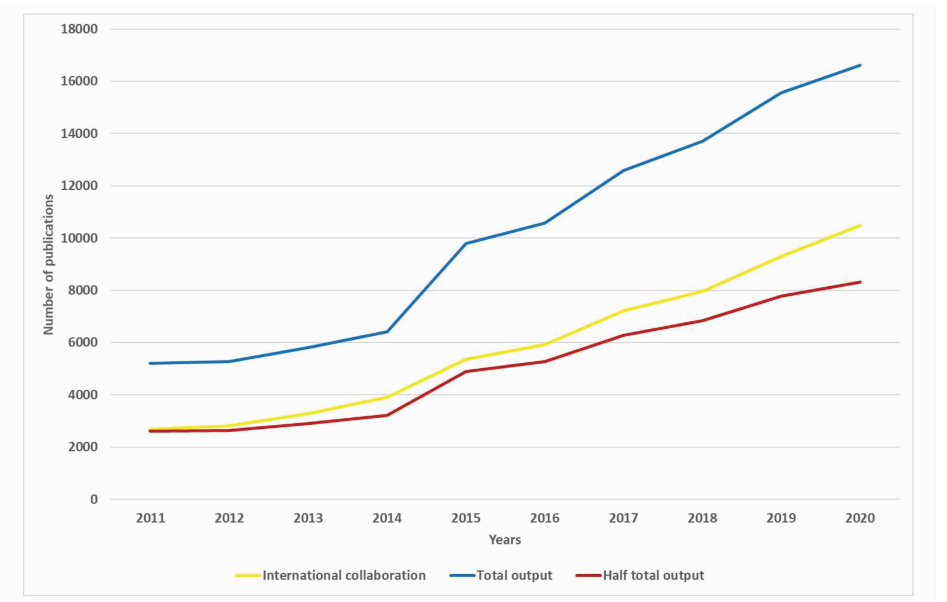

Figure 1 Scientific production and international collaboration in the West African science (2011-2020).

Table 3 International collaboration in West African science (2011-2020)

Year		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total output		5,203	5,273	5,801	6,423	9,804	10,569	12,582	13,701	15,562	16,628
International collaboration	#	2,671	2,804	3,287	3,901	5,362	5,919	7,211	7,962	9,294	10,481
	%	51.34	53.18	56.66	60.73	54.69	56.00	57.31	58.11	59.72	63.03

Table 4 West African countries' international collaboration rate (2011-2020)

Country	Total output		International collaboration	
	# papers	Rank	# papers	Rate
Benin	4,389	5	3,595	81.91
Burkina Faso	5,184	4	4,502	86.84
Cape Verde	352	15	337	95.74
Cote d´Ivoire	4,255	6	3,264	76.71
Gambia (The)	1,920	8	1,813	94.43
Ghana	19,387	2	13,143	67.79
Guinea	1,114	12	1,020	91.56
Guinea Bissau	526	14	522	99.24

Country	Total output		International collaboration	
	# papers	Rank	# papers	Rate
Liberia	648	13	609	93.98
Mali	2,905	7	2,686	92.46
Niger	1,682	9	1,519	90.31
Nigeria	57,255	1	27,001	47.16
Senegal	7,018	3	5,453	77.70
Sierra Leone	1,333	11	1,265	94.90
Togo	1,389	10	1,082	77.90
ECOWAS	101,546		58,892	58.00

5.3 Country partnership

Table 5 gives the top 20 partner countries of West Africa. The USA, UK and France keep the first places. Germany, ranked 4th in the previous decade (Mêgnigbêto, 2013a), is now ranked 6th, and South Africa has improved its ranking, moving from 5th to 4th place, while new actors like China (5th) earns many places, moving from 16th to 5th. Malaysia, which did not belong to this list, appears now and ranks 7th, before Belgium, Canada, etc. South Africa, Kenya and Cameroun are the only African countries that appear in the list. Table 6 produces the top-10 partner countries per continent, and Table 7 gives the West African source countries of the top-6 West African partner countries and their shares; they are the eight main producers: Nigeria, Ghana, Senegal, Burkina Faso, Benin, Cote d'Ivoire, Mali and The Gambia. Nigeria and Ghana, in this order, appear at the top everywhere except in the France list, where four French-speaking countries are aligned before Nigeria takes the 5th place. One of the smaller producers, Sierra Leone, appears to be the third partner of China in West Africa.

Table 5 Top 20 partner countries of West African countries (2011-2020)

Rank	Country	Share	
		#	%
1	USA	15,540	15.30
2	UK	11,354	11.18
3	France	8,630	8.50
4	South Africa	8,406	8.28
5	China	4,533	4.46
6	Germany	4,485	4.42
7	Malaysia	3,958	3.90
8	Canada	3,403	3.35
9	Switzerland	3,109	3.06
10	Australia	3,079	3.03
11	India	2,924	2.88
12	Netherlands (The)	2,777	2.73
13	Belgium	2,745	2.70
14	Kenya	2,395	2.36
15	Italy	2,226	2.19

Rank	Country	Share	
		#	%
16	Brazil	1,703	1.68
17	Spain	1,695	1.67
18	Cameroon	1,651	1.63
19	Sweden	1,641	1.62
20	Japan	1,597	1.57

Table 6 Top 20 partner countries of West African countries by continent (2011-2020)

America		Europe		Asia		Africa	
USA	15.30	UK	11.18	China	4.46	South Africa	8.28
Canada	3.35	France	8.50	Malaysia	3.90	Kenya	2.36
Brazil	1.68	Germany	4.42	India	2.88	Cameroon	1.63
Mexico	0.73	Switzerland	3.06	Japan	1.57	Uganda	1.38
Peru	0.44	Netherlands (The)	2.73	Saudi Arabia	1.00	Ethiopia	0.94
Argentina	0.41	Belgium	2.70	Pakistan	0.98	Egypt	0.88
Philippines	0.39	Italy	2.19	Turkey	0.94	Morocco	0.55
		Spain	1.67	Vietnam	0.75	Zambia	0.51
		Sweden	1.62	Iran	0.71	Congo DR	0.50
		Denmark	1.47	South Korea	0.67	Mozambique	0.45

Table 7 West African source countries of West African partner countries

USA		UK		France	
Nigeria	6.11	Nigeria	4.89	Senegal	2.59
Ghana	4.16	Ghana	3.00	Burkina Faso	1.62
Senegal	1.44	Gambia (The)	1.20	Cote d´Ivoire	1.47
Mali	1.21	Burkina Faso	0.83	Benin	1.32
Burkina Faso	1.00	Senegal	0.73	Nigeria	0.91
South Africa		**China**		**Germany**	
Nigeria	5.64	Nigeria	2.3	Nigeria	1.65
Ghana	1.86	Ghana	1.57	Ghana	1.29
Senegal	0.37	Sierra Leone	0.15	Burkina Faso	0.51
Burkina Faso	0.31	Cote d´Ivoire	0.14	Cote d´Ivoire	0.41
Benin	0.30	Benin	0.14	Benin	0.39

Figure 2, plotted with Pajek software (de Nooy et al., 2011), represents the network of countries involved in the scientific collaboration in West African science. It shows, in the centre, major contributors: Nigeria, Ghana (in West Africa, marked with the number 1) and UK, the USA, France, South Africa, etc. (marked with the number 0). It also shows that Nigeria has strong ties with the USA, UK, France, has ties with almost all the partners and connects the region with Asian countries (at the bottom of the figure: Vietnam, Turkey, South Korea, Saudi Arabia, Pakistan, Malaysia, Iran, etc.), Eastern (Tanzania, Kenya, Uganda,

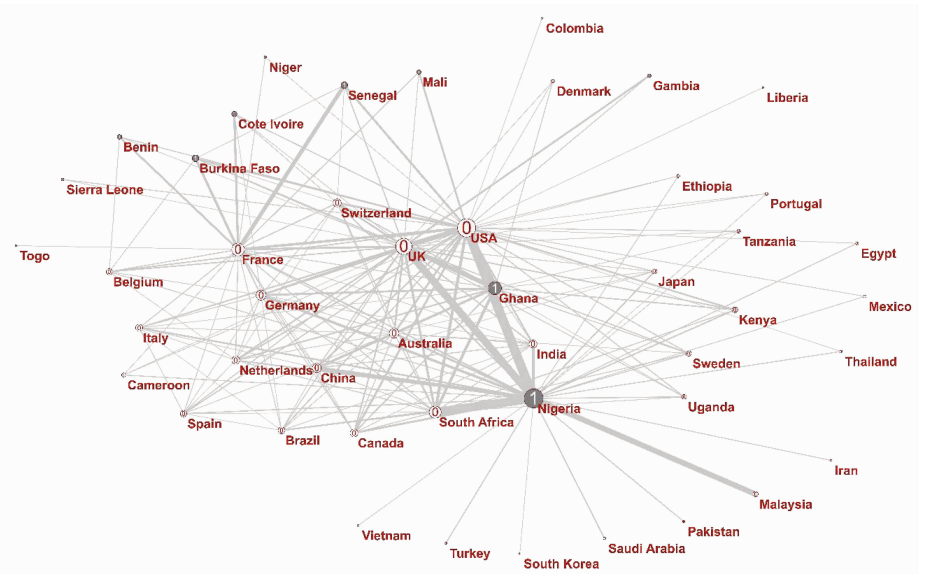

Figure 2 Network of countries involved in international collaboration in West African science (2011-2020).

Ethiopia) and Northern Africa (Egypt). In a nutshell, Nigeria, serves as a hub for West Africa to the rest of the world. In this figure, the width of lines indicates the intensity of collaboration, and the size of circles represents countries the level of output.

5.4 Institutional partners

At the institutional level, the top partners of West Africa have home addresses in the main partner countries (UK, France and USA). University of London (UK) is the first institutional partner; it contributes 4.38% to regional science. Then, come Covenant University from the USA (3.01%) and two French institutions, the Institut de Recherche pour le Dêveloppement (2.82%) and the Centre National de la Recherche Scientifique (2.56%) (Table 8). The only African institution appearing in the list is based in South Africa (University of Cape Town), and ranked 13th with 1.27%), meaning that the main institutional partners of West Africa are non-African. Out of the 17 institutions with a share greater than or equal to 1%, one is an international organisation (World Health Organisation); among the remaining, one is African (South African), 16 are from the Western of which 5 from UK, 4 from the USA and 5 from France. In summary, not only are the main partner countries out of Africa, but the main institutional partners are out of Africa also.

Table 8 Top institutional partners of West Africa (2010-2020, share ≥ 1%)

Rank	Institution	Country	Share (%)
1	University of London	UK	4.377
3	Covenant University	USA	3.013
4	Institut de Recherche pour le Développement	France	2.819
5	Centre National de la Recherche Scientifique	France	2.555
6	World Health Organisation	N/A	1.871

Rank	Institution	Country	Share (%)
7	University of California System	USA	1.609
8	Institut National de la Santé et de la Recherche Médicale	France	1.556
9	University of Witwatersrand	UK	1.484
10	Harvard University	UK	1.450
11	Université de Montpellier	France	1.365
12	Centre international de coopération et de recherche agronomique en développement	France	1.353
13	University of Cape Town	South	1.271
14	National Institute of Health	USA	1.261
15	Johns Hopkins University	USA	1.218
16	University of Oxford	UK	1.159

5.5 Intraregional collaboration

Intraregional collaboration is understood as the collaboration that implies at least two West African countries, either with or without the participation of one non-West African country. We introduce i) the bilateral intraregional collaboration, which means the collaboration between two countries within the region; ii) the (country-oriented) intraregional collaboration, which considers the papers one country of the region shares with the rest of the region; and iii) the region-oriented intraregional collaboration which considers the total number of papers resulting from intraregional collaboration within the region.

Within the collected bibliographic data, 5,714 records result from intraregional collaboration, which indicates an intraregional collaboration rate of 5.42%; this number varies from country to country, however. Table 9 shows data on intraregional collaboration per West African country: the number of papers (and the associated rate) a country (in the header of column) shares with another country (in the header of line). As an illustration, Benin (header of column 2) published with Burkina Faso (header of line 4) 286 papers (bilateral intraregional collaboration), equating to 6.52% of Benin's total publications. The last line of the table indicates both the number of papers the country in the header of the column shares with the rest of West Africa and its share of the country's total output, i.e., its contribution to the intraregional science (the country-oriented intraregional collaboration data): for example, Benin published with the rest of West Africa 1,151 papers representing 26.22% of its total output (indicating that Benin country-oriented intraregional collaboration rate is 26.22%).

Figure 3 plots, for each country, both the country-oriented and the region-oriented intraregional collaboration rates. It shows that Togo has the highest (country-oriented) intraregional collaboration rate and Nigeria the lowest one; indeed, Togo and Nigeria produced 1,392 and 59,027 papers, respectively, and shared 592 (42.62%) and 2,187 (3.52%) of them respectively with the rest of West Africa. On the other hand, when the total papers resulting from intraregional collaboration are considered (5,714 papers), the number of papers Togo shared with the region represents 10.36%, and the Nigerian one 38.27%, meaning that Togo contributed about 10% of the papers from intraregional collaboration in West Africa and Nigeria 38.27%; that are these countries region-oriented intraregional collaboration rates. Globally, small producers have higher country-oriented collaboration rates and bigger producers lower ones; conversely, bigger producers have higher region-oriented collaboration rates and small producers lower ones.

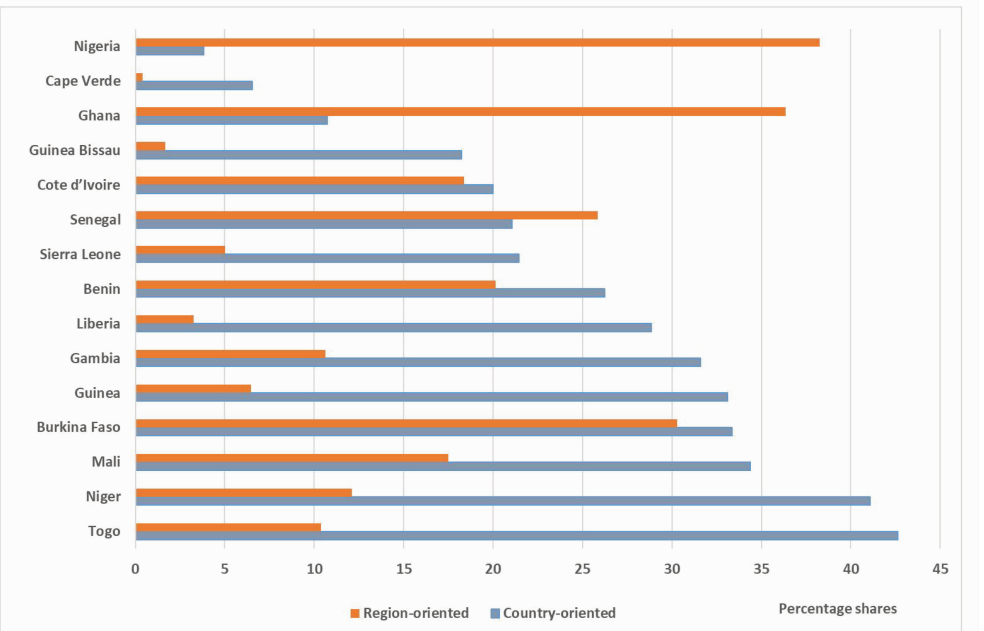

Figure 3 Country-oriented and region-oriented intraregional collaboration rates of West African countries (2011-2020)

Table 9 Intraregional collaboration in West African science (2011-2020)

	Benin		Burkina Faso		Cape Verde		Cote d´Ivoire		Gambia (The)		Ghana		Guinea		Guinea Bissau	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Benin	—	—	286	5.52	0	0.00	256	4.87	46	2.40	286	1.48	80	7.18	6	1.14
Burkina Faso	286	6.52	—	—	0	0.00	356	6.77	141	7.34	415	2.14	102	9.16	28	5.32
Cape Verde	0	0.00	0	0.00	—	—	1	0.02	0	0.00	8	0.04	3	0.27	2	0.38
Cote d´Ivoire	256	5.83	356	6.87	1	0.28	—	—	46	2.40	223	1.15	111	9.96	11	2.09
Gambia (The)	46	1.05	141	2.72	0	0.00	46	0.88	—	—	156	0.80	28	2.51	47	8.94
Ghana	286	6.52	415	8.01	8	2.27	223	4.24	156	8.13	—	—	47	4.22	27	5.13
Guinea	80	1.82	102	1.97	3	0.85	111	2.11	28	1.46	47	0.24	—	—	6	1.14
Guinea Bissau	6	0.14	28	0.54	2	0.57	11	0.21	47	2.45	27	0.14	6	0.54	––	––
Liberia	17	0.39	18	0.35	1	0.28	23	0.44	7	0.36	69	0.36	26	2.33	3	0.57
Mali	143	3.26	383	7.39	1	0.28	172	3.27	152	7.92	208	1.07	61	5.48	12	2.28
Niger	123	2.80	209	4.03	1	0.28	88	1.67	27	1.41	110	0.57	54	4.85	5	0.95
Nigeria	317	7.22	260	5.02	5	1.42	189	3.60	204	10.63	1,104	5.69	57	5.12	17	3.23
Senegal	212	4.83	470	9.07	17	4.83	310	5.90	146	7.60	270	1.39	131	11.76	38	7.22
Sierra Leone	22	0.50	38	0.73	0	0.00	24	0.46	15	0.78	84	0.43	42	3.77	2	0.38
Togo	181	4.12	218	4.21	2	0.57	170	3.24	23	1.20	122	0.63	42	3.77	6	1.14
West Africa	1,151	26.22	1,730	33.37	23	6.53	1,051	20.00	607	31.61	2,078	10.72	369	33.12	96	18.25

Table 9 (continuous). Intraregional collaboration in West African science (2011-2020)

	Liberia		Mali		Niger		Nigeria		Senegal		Sierra Leone		Togo	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Benin	17	2.62	143	4.92	123	7.3	317	0.55	212	3.02	22	1.65	181	13.03
Burkina Faso	18	2.78	383	13.18	209	12.4	260	0.45	470	6.70	38	2.85	218	15.69
Cape Verde	1	0.15	1	0.03	1	0.1	5	0.01	17	0.24	0	0.00	2	0.14
Cote d´Ivoire	23	3.55	172	5.92	88	5.2	189	0.33	310	4.42	24	1.80	170	12.24
Gambia (The)	7	1.08	152	5.23	27	1.6	204	0.36	146	2.08	15	1.13	23	1.66
Ghana	69	10.65	208	7.16	110	6.5	1,104	1.93	270	3.85	84	6.30	122	8.78
Guinea	26	4.01	61	2.10	54	3.2	57	0.10	131	1.87	42	3.15	42	3.02
Guinea Bissau	3	0.46	12	0.41	5	0.3	17	0.03	38	0.54	2	0.15	6	0.43
Liberia	—	—	15	0.52	6	0.4	68	0.12	28	0.40	48	3.60	11	0.79
Mali	15	2.31	—	—	147	8.7	171	0.30	332	4.73	24	1.80	79	5.69
Niger	6	0.93	147	5.06	—	—	251	0.44	213	3.04	17	1.28	58	4.18
Nigeria	68	10.49	171	5.89	251	14.9	—	—	247	3.52	121	9.08	145	10.44
Senegal	28	4.32	332	11.43	213	12.7	247	0.43	—	—	54	4.05	121	8.71
Sierra Leone	48	7.41	24	0.83	17	1.0	121	0.21	54	0.77	—	—	11	0.79
Togo	11	1.70	79	2.72	58	3.4	145	0.25	121	1.72	11	0.83	—	—
West Africa	187	28.86	999	34.39	691	41.1	2,187	3.82	1,478	21.06	286	21.46	592	42.62

5.6 Fields of specialisation

We distributed papers according to the Frascati Manual's fields of R&D classification (OECD, 2015, p. 59) using the mapping between Web of science classification scheme and the Frascati Manual's ones provided by Clarivate Analytics (Clarivate Analytics, 2012), distinguishing internationally co-authored papers (named here "International") and the domestic papers. Further, we computed in Table 10 the activity index or specialisation index[5] and the relative specialisation index (RSI)[6], taking the current West African production as a reference[7]. It comes out that Medical and health sciences have the highest share of the total output of the region (42.31% of papers), followed by *Natural sciences* (34.37%), *Social sciences* (11.72%), *Engineering and technology* (11.65%), *Agricultural and veterinary sciences* (9.16%), and at the rear *Humanities and the arts* (1.94%). The activity index informs that the internationally co-authored papers and the domestic ones deal with *Medical and health sciences* and *Agricultural and veterinary sciences* as average as the overall West African papers. While "international" papers specialise more in *Engineering and technology* (AI = 1.06) and in *Natural sciences* (AI = 1.16), the domestic ones are under-specialised in these fields (AI = 0.92

5 The activity index was borrowed from economics and introduced in informetrics by Frame (1977). It is defined as follows (European Commission, 1997, p. M-22-M-23; Glanzel, 2000, p. 126; Schneider, 2010, p. 18):

$$AI = \frac{\text{the world share of a given country in publications in the given field}}{\text{the overall world share of the given country in publications}}$$

or, equivalently

$$AI = \frac{\text{the share of the given field in the publications of the given country}}{\text{the share of the given field in the word total of publications}}$$

6 $RSI = \frac{AI-1}{AI+1}$. While the AI is higher than or equal to 0, the RSI varies from-1 to 1. "RSI =-1 indicates a completely inactive research field, RSI = 1 if only the given field is active. RSI < 0 indicates a lower-than-average, RSI > 0 a higher-than-average activity; RSI = 0 reflects a completely balanced, "average" situation (European Commission, 1997, p. M-22-M-23; Glanzel, 2000, p. 126; Schneider, 2010, p. 18).

7 The definition of the indicator takes the world as reference; however, in order to compare countries with those of similar socio-economic and cultural situation, we took the West Africa as reference. Due to this, the global papers RSI become the normal one.

and 0.78 respectively). However, the reverse is recorded in *Social sciences* and *Humanities and the arts*, where domestic papers overspecialise (AI = 1.35 and 1.70 respectively) and international papers are under-specialised (AI = 0.74 and 0.49 respectively).

The values of the relative specialisation indexes (Figure 4) display the same patterns. Indeed, international papers have as average activity as the overall production of the region in *Medical and health sciences* and *Agricultural* and *veterinary sciences* (RSI=0); they display positive (but closer to 0) values (RSI=0.07 and 0.03 respectively) in *Natural sciences* and *Engineering and technology*, traducing an activity little higher than the overall one of the region in these fields; international papers have more pronounced negative values in *Social sciences* and *Humanities and the arts* (RSI =-0.15 and -0.34 respectively, traducing an activity lower than the overall one of the region. Domestic papers have similar activity to international papers in *Medical and health sciences* and *Agricultural and veterinary sciences* (RSI = -0.01 and 0.01), but opposite activity in the remaining fields: higher than the regional overall activity in *Social sciences* and *Humanities and the arts* (RSI=0.15 and 0.26 respectively) and lower in *Natural sciences* and *Engineering and technology* (RSI=-0.12 and -0.04 respectively).

In summary, at the regional level, international papers have higher than average activity in *Natural sciences* and *Engineering and technology*, whereas domestic ones have in *Social sciences* and *Humanities and the arts*; both have an average activity in *Medical and health sciences* and *Agricultural and veterinary sciences*.

Table 10 West African activity index for domestic and internationally co-authored papers

	Output		"International" papers		Domestic papers	
	# papers	Share (%)	# papers	Activity index	# papers	Activity index
Natural sciences	34,902	34.37	23,469	1.16	11,433	0.78
Engineering and technology	11,826	11.65	7,236	1.06	4,590	0.92
Medical and health sciences	42,960	42.31	25,122	1.01	17,838	0.99
Agricultural and veterinary sciences	9,298	9.16	5,342	0.99	3,956	1.01
Social sciences	11,897	11.72	5,128	0.74	6,769	1.35
Humanities and the arts	1,965	1.94	558	0.49	1,407	1.70

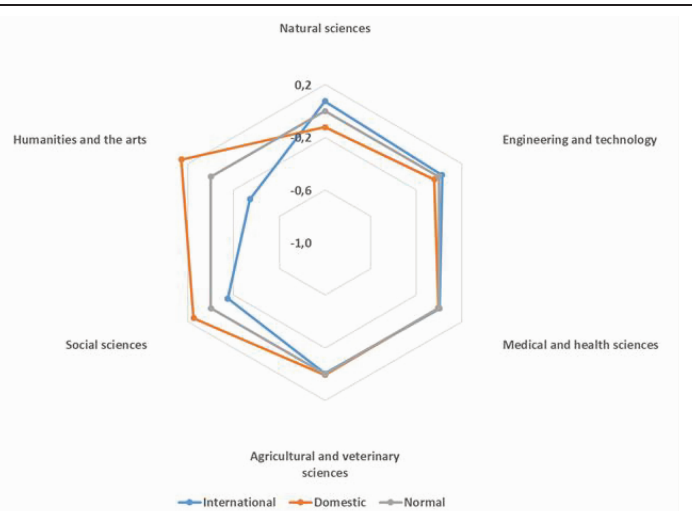

Figure 4 Relative specialisation indexes of West Africa (2011-2020).

6 Discussion

The West African scientific output over the decade 2011-2020 has tripled as compared to the previous decade, suggesting more research activity than ever. The rapid growth in the continent's scientific output was yet reported by Confraria and Godinho (2015), suggesting a possible take-off of African science is taking place. The same was registered by Mêgnigbêto (2021) who reported that all African regions had produced speeder than the world, and West Africa has the highest speed, so the share of West Africa to the global science went from 0.19% over the decade 2001-2010 to 0.37% over the decade 2011-2020[8]. At such a speed, the gap between the global science production and the African or West African one would be bridged, and as the United Nations Economic Commission for Africa (2014, p. 12) foresaw, Africa may start to compete internationally as an emerging science producer. Mêgnigbêto (2021) noticed that not all countries have the same dynamics: the smaller producers speed is higher than that of the remaining countries, because they have probably a weak research infrastructure, become aware of it and engage process to improve it in order to face development challenges (Commission de la CEDEAO, 2012; Sooryamoorthy 2020). However, the ranking of the West African countries according to their total output remains unchanged, as compared to the one over the previous decade (cf. Mêgnigbêto, 2013a, and 2016): Nigeria is still the local giant with more than half, followed by Ghana (20%), Senegal (10%), etc. The gap between the first two countries and the rest of the region is still large; indeed, these two countries, on their own, hold three quarters of the regional publication. This stresses the skewness of the distribution of publications among countries that led Mêgnigbêto (2021, p. 388) to divide the region countries into clusters according to their share of the total regional output[9].

The increase in co-authorship accompanies the increase in the volume of production. West Africa is then following the world dynamics because co-authorship has been increasing (Leydesdorff & Wagner, 2008; Mêgnigbêto, 2013a, 2016; Toivanen & Ponomariov, 2011) and has exploded recently (Adams, 2012). It indicates that more researchers are active in the region, of which cause may be the diversification of fields of training at university, the increase in number of students being enrolled, in general, and particularly in master or doctoral studies; the growing rate is estimated at 15% over the decade 2001-2010 (United Nations Economic Commission for Africa, 2014, p. 3).

The international collaboration rate also increases both at a regional level and individual countries level. Excepting Nigeria, almost all West African countries have collaborated with other countries on more than half their total output. This relatively high rate is a sign of both dependency on abroad on the one hand and information and knowledge sharing with the rest of the world on the other hand. Because science is being globalised, the increase in the international collaboration rate could also be interpreted as the measurement of the extent

8 We computed these statistics based one data we collected from Web of Science on March 20th 2022.

9 i) Cluster 1 (small producers), grouping countries with at most 2% of the regional output: The Gambia, Niger, Togo, Sierra Leone, Guinea, Liberia, Guinea Bissau and Cape Verde; ii) cluster 2 (lower intermediate producers), grouping countries with contribution higher than 2% and less than 5% of the regional output: Benin, Cote d'Ivoire and Mali; iii) cluster 3 (upper intermediate producers), grouping countries with contribution falling between 5% and 15% of that of the region: Senegal, Burkina Faso; iv) cluster 4 (high producer), countries with contribution higher than 15% and lower than 50% the total of the region: it is constituted with Ghana only; and, v) cluster 5 (highest producer), grouping countries with contribution higher than 50% the total of the region: it is constituted with Nigeria only.

to which the region is embedded in the globalisation of science, expanding its research quality or varying its partners. For comparison purpose, Table 11 gives the international collaboration rate of some developed countries and South Africa;[10] it shows that France has a rate similar to the one of West Africa and Belgium a larger one; Glänzel (2001, p. 73) also encountered such a level of international collaboration rate in European Union. Traditional partner countries are still the top partners (the UK and France, the colonial power, and the USA, a global research partner), but new partner countries are appearing or moving up, like China and Malaysia, probably as an outcome of the multiplication of strategic partnerships with the continent (Mêgnigbêto, 2021; cf. Muchie & Patra, 2020 for the case of China). The African Union Commission (2014, p. 18) notices that bilateral and multilateral partnerships have shaped STI development in Africa (e.g., the European Union– Africa Joint Strategy, the India– Africa Science and Technology Initiatives and the China – Africa Science and Technology Partnership). At the national level, the international collaboration rate seems to conform to the finding of Boshoff (2009, 2010) and Glanzel (2001) that small producers tend to have higher international collaboration rates. The weak intraregional collaboration rate is an indicator of the absence of collaboration among the West African countries; the phenomenon was also noticed, for instance, in trade and transportation (African Development Bank & African Development Fund, 2011; Boshoff, 2009, 2010; Mêgnigbêto, 2016; Toivanen & Ponomariov, 2011).

Table 11 International collaboration rates of South Africa and some Western countries for 2011-2020 computed from Web of Science

	Output	International collaboration	
		# papers	Rate
USA	6,974,390	2,190,399	31.41
Japan	1,231,223	345,681	28.08
Germany	1,665,421	844,623	50.72
Belgium	334,733	218,816	65.37
Canada	1,069,182	532,720	49.83
France	1,118,139	617,410	55.22
South Africa	198,637	103,275	51.99

International and domestic papers operate as if they divided the fields of science into "influence zones", having the same level of activity in Medical and health sciences and Agricultural and veterinary sciences but leaving Natural sciences and Engineering and technology to internationally co-authored papers, and Social sciences and Humanities and the arts to domestic ones. The RSI for Agricultural and veterinary sciences is positive and closer to 0, where even some developed countries have negative values (see, for example, Glänzel, 2001; and Schneider, 2010); this situation may be explained by the fact the region owns lands that favour the production of agricultural resources (ECOWAS Commission, 2005, 2010; FAO Regional Office for Africa, 2014; N'Zué , 2014).and, as a consequence, national development plans always recognize agriculture as the "backbone of the economy" (ECOWAS Commission, 2005). Note, however, that West Africa has not reached food security yet and continues

10 We have searched the Web of Science for these data and computed the international collaboration rates.

importing some agricultural products like rice and wheat from Asia and Europe.

The reason for the specialisation in Agricultural and veterinary sciences and in Medical and health sciences for both domestic and international papers (and the global one, cf. Mêgnigbêto, 2021, p. 386) is both historical and logical. From a historical point of view, modern research foundations were laid down in Africa before the independence by former colonial powers (Taylor, 1991; UNESCO, 1986) that set up institutions specialised mainly in agriculture in French colonies[11] and agriculture and health and medicine in English colonies[12] (UNESCO, 1986, p. 14); the coloniser needed people to be well fed and healthy to better exploit them and their natural resources European industries required (Dahoun, 1997). From the logical point of view, one needs to feed himself and be healthy to generate wealth; as an illustration, the Science, Technology and Innovation Strategy for Africa 2014-2024 (Africa Union Commission, 2014, p. 22) strengthened this logical reason by setting the first two priorities of its strategic orientation around food security and health[13]. *Natural sciences* and *Engineering and technology* require heavy investment and major experience countries could not provide, so researchers rely on abroad; as far as *Social sciences* and *Humanities and the arts* are concerned, they question local problems that need to be solved by domestic researchers.

7 Conclusion

Collaboration in the West African science was studied in this paper, with the three-fold objective of drawing the landscape of scientific publication in the region over the period 2011-2020, updating science collaboration indicators in the region and comparing results with the one of the previous decade. Analyses showed that West African science is growing faster than the one of the world; in one decade, the region tripled its production and, consequently, West Africa and Africa are reducing the gap with the World production. At the national level, the dynamics are not of the same level, because small producers have output speeder than the higher ones. Co-authorship is trending upward: the number of authors per paper had gone from 4.82 in 2001-2010 to the value of 6.49 in 2011-2020, showing the same trend observed at the global level. UK, France, and the USA are keeping the first place as country partners, followed by South Africa, the unique African partner country within the top-20 partner countries list. New partnerships are having an effect: China and Malaysia are on the list. The former has intensified its relationships with the region, so it has improved its ranking as compared to the previous decades, the latter appearing for the first time in this list. At the institutional level, the main partners reside in the partner countries; they are mainly universities, government research centres and international organisations like World Health Organisation. The study also sought to measure the field of science specialisation of domestic and internationally co-authored papers. It appears globally that if the two categories of papers have neutral positions in *Medical and health sciences* and *Agricultural and veterinary sciences*, domestic papers reserved *Social sciences* and *Humanities and the arts*,

11 They are : i) Office de la Recherche Scientifique et Technique d'Outre-Mer, ii) Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières, iii) Institut de Recherches du Coton et de Textiles Exotiques, iv) Institut Francais, du Café , du Cacao et autres Plantes Stimulantes, v) Institut de Recherches pour les Huiles et Oléagineux.

12 They are : i) West African Cocoa Research Institute, ii) West African Institute for Oil-Palm Research, iii) West African Maize Research Unite, iv) West African Rice Research Station, iv) West African Institute of Social and Economic Research and v) West African Council for Medical Research.

13 "Priority 1: Eradication of hunger and achieving food Security" and "Priority 2: Prevention and control of diseases" (Africa Union Commission, 2014, p. 22)

and international papers *Natural sciences* and *Engineering and technology.*

References

Adams, J. (2012) . Collaborations : The rise of research networks. *Nature, 490* (7420) , 335–336. https://doi.org/10.1038/490335a

Adams, J. (2013) . The fourth age of research. *Nature, 497* (7420) , 557–560. https://doi.org/10.1038/490335a

Adams, J., Gurney, K., Hook, D., & Leydesdorff, L. (2014) . International collaboration clusters in Africa. *Scientometrics, 98* (1) , 547–556. https://doi.org/10.1007/s11192–013–1060–2

Adams, J., King, C., & Hook, D. (2010) . *Global research report* : *Africa*. Thomson Reuters.

Africa Union Commission. (2005) . *Africa´s science and technology consolidated plan of action.* African Union Commission.

Africa Union Commission. (2014) . *On the wings of innovation : Science, technology and innovation strategy for Africa* (STISA–2024) . African Union Commission.

Africa Union Commission. (2015) . *Agenda 2063 : The Africa we want.* African Union Commission.

Africa Union Commission. (2020) . *Member States.* African Union Commission. https://au.int/en/member_states/countryprofiles2

African Development Bank, & African Development Fund. (2011) . *Regional integration strategy paper for West Africa 2011 – 2015*. African Development Bank.

African Union Commission & New Zealand Ministry of Foreign Affairs and Trade. (2014) . *African Union handbook: A guide for those working with and within the African Union* (1st edition) . African Union Commission and New Zealand Ministry of Foreign Affairs and Trade. http://au.int/en/sites/default/files/MFA% 20AU% 20Handbook%20–%20Text%20v10b%20interactive.pdf

African Union Development Agency. (2019) . *African innovation outlook III*. African Union Development Agency.

Bénin. Ministère d´Etat chargé du plan et du développement. (2018) . *Plan national de développement 2018–2025*. Ministère d´Etat chargé du plan et du développement. http://extwprlegs1.fao.org/docs/pdf/Ben183074.pdf

Bordons, M., & Gomez, I. (2000) . Collaboration networks in science. In B. Cronin & H. B. Atkins (Eds.) , *The Web of Knowledge : A festschrift in honor of Eugene Garfield* (p. 197–213) . Information Today.

Boshoff, N. (2009) . Neo–colonialism and research collaboration in Central Africa. *Scientometrics, 81* (2), 413–434.

Boshoff, N. (2010) . South– South research collaboration of countries in the Southern African Development Community (SADC) . *Scientometrics, 84* (2) , 416–434.

Burkina Faso. Gouvernement du Burkina Faso. (2021) . *Plan national de développement économique et social 2021–2025* (PNDES–II) . Gouvernement du Burkina Faso. https://www.finances.gov.bf/fileadmin/user_upload/storage/PNDES–II_Document_de_Strategie.pdf

Cabo Verde. Governo de Cabo Verde. (2017) . P*EDS : plano stratégico de desenvolvimento sustentável 2017/2021 : Cabo Verde. Governo de Cabo Verde.* https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/peds_plano_estrategtico_de_desenvolvimento_sustentavel_2017–2021.pdf

Clarivate Analytics. (2012) . *OECD category scheme.* http://help.incites.clarivate.com/inCites2Live/filterValues–Group/researchAreaSchema/oecdCategoryScheme.html

Commission de la CEDEAO. (2012) . *Politique science, technologie et innovation (ECOPOST)* : *2013–2017.* Commission de la CEDEAO.

Confraria, H., & Godinho, M. M. (2015) . The impact of African science : A bibliometric analysis. *Scientometrics, 102* (2) , 1241–1268. https://doi.org/10.1007/s11192–014–1463–8

Cote d´Ivoire. Ministère du plan et du développement. (2016) . *Plan national de développement 2016–2020?: Diagnostique stratégique de la Côte d´Ivoire sur la trajectoire de l´émergence. Tome 1*. Ministère du plan et du développement. https://www.gcpnd.gouv.ci/fichier/doc/TOME1_compresse.pdf

Dahoun, A. M. C. (1997) . *Le statut de la science et de la recherche au Bénin : Contribution à la sociologie des sciences des pays en développement*. Logos.

Davis, C. H. (1983) . L´UNESCO et la promotion des politiques scientifiques nationales en Afrique Sub–sahari–enne, 1960–1979. *études internationales, 14* (4) , 621–638. https://doi.org/10.7202/701577ar

de Nooy, W., Mrvar, A., & Batagelj, V. (2011) . *Exploratory social network analysis with Pajek* (revised and ex–panded second edition) . Cambridge University Press.

de Smet, E. (2009a) . ABCD: a new FOSS library automation solution based on ISIS. *Information Develop–ment, 25* (1) , 61–67.

de Smet, E. (2009b) . *The abc of ABCD* : *the reference manual : Version 1.0*. http://bvsmodelo.bvsalud.org/download/abcd/manuais/ABCofABCD_atualizado.pdf

ECOWAS Commission. (2005) . *Regional agricultural policy for West Africa : ECOWAP: make agriculture the lever of regional integration*. ECOWAS Commission. https://www.diplomatie.gouv.fr/IMG/pdf/01_ANG–Com–CEDEAO.pdf

ECOWAS Commission. (2010) . *West African common industrial policy—WACIP*. ECOWAS Commission.

ECOWAS Commission. (2011) . *ECOWAS vision 2020: Towards a democratic and prosperous community*. E–COWAS Commission.

Essegbey, G., Diaby, N., & Konte, A. (2015) . West Africa. In *UNESCO Science report : Toward 2030* (p. 471–498) . UNESCO Publishing.

European Commission. (1997) . *Second European report on science and technology indicators : Appendix*. Of–fice for Official Publications of the European Communities. https://op.europa.eu/o/opportal–service/download–handler?identifier=4b023e01–0777–4b0c–9a97–973def052513&format=PDF&language=en&productionSys–tem=cellar&documentIdentifier=4b023e01–0777–4b0c–9a97–973def052513.0002

FAO Regional Office for Africa. (2014) . *FAO statistical yearbook 2014 : Africa food and agriculture*. FAO Re–gional Office for Africa.

Frame, J. D. (1977) . Mainstream research in Latin America and the Caribbean. *Interciencia, 2* (3) , 143–148.

Ghana. National Development Planning Commission. (2021) . *Medium–term national development policy framework : National medium–term development policy framework 2022–2025*. Government of Ghana. https://ndpc.gov.gh/media/MTNDPF_2022–2025_Dec–2021.pdf

Glänzel, W. (2000) . Science in Scandinavia : A bibliometric approach. *Scientometrics, 48* (2) , 121–150. https://doi.org/10.1023/A:1005640604267

Glänzel, W. (2001) . National characteristics in international scientific co–authorship relations. *Scientometrics, 51* (1) , 69–115.

Glänzel, W., & Schubert, A. (2005) . Analysing scientific networks through co–authorship. In H. F. Moed, W. Glänzel, & U. Schmoch (Eds.) , *Handbook of quantitative science and technology research : The use of publication and patent statistics in studies of S&T systems* (p. 257–276) . Kluwers academic publisher. https://link.springer.com/chapter/10.1007/1–4020–2755–9_12

Guinea Bissau. Gouvernement de Guinée Bissau. (2015) . *Plan stratégique et opérationnel 2015–2020*《Ter–ra Ranka》. Gouvernement de Guinée Bissau. https://www.acci–cavie.org/wp–content/uploads/2021/05/Plan–Guinee–Bissau–2015.pdf

Guinée. Ministère du Plan et de la Coopération Internationale. (2016) . *Plan national de développement économique et social 2016–2020. Volume 1: Document principal*. Ministère du Plan et de la Coopération In–ternationale. https://pndesguinee.org/images/documents/pndes/PNDES%20Volume%201.pdf

Gurib–Fak, A., & Signé, L. (2022) . Investment in science and technology is key to an African economic boom. In A. U. Ordu (Ed.) , *Foresight Africa : Top priorities for the continent in 2022* (p. 15–16) . Africa growth initiative. https://www.brookings.edu/wp–content/uploads/2022/01/foresightafrica2022_fullreport.pdf

Katz, J. S., & Martin, B. R. (1997) . What is research collaboration?. *Research Policy, 26* (1) , 1–18.

Leydesdorff, L., Wagner, C., Park, H.–W., & Adams, J. (2013) . International collaboration in science : The global map and the network. *El profesional de la información, January–February, 22* (1) , 87?94. http://dx.doi.org/10.3145/epi.2013.ene.12

Leydesdorff, L., & Wagner, C. S. (2008) . International collaboration in science and the formation of a core group. *Journal of Informetrics, 2* (4) , 317–325.

Liberia. Government of Liberia. (2018) . *Pro–poor agenda for prosperity and development (PAPD)* . Government of Liberia. https://www.mfdp.gov.lr/index.php/docs/national–development–plan/pro–poor–agenda–for–prosperity–and–development–papd/download

Mali. Gouvernement du Mali. (2019) . *Rapport national volontaire sur la mis en oeuvre des Objectifs de Développements Durable. Forum politique de haut niveau sur le développement durable.* Gouvernement du Mali. https://sustainabledevelopment.un.org/content/documents/20200Projet_de_RNV_ODD_VFcor2_06_06_2018_Actuel.pdf

Mêgnigbêto, E. (2012) . Scientific publishing in West Africa : A comparison of Benin with Senegal and Ghana. In E. Archambault, Y. Gringras, & V. Larivière (Eds.) , *Proceedings of STI 2012 Montréal* (Vol. 2, p. 589?600) . Science–Metrix; Observatoire des Sciences et Technologies.

Mêgnigbêto, E. (2013a) . International collaboration in scientific publishing : The case of West Africa (2001–2010) . *Scientometrics, 96* (3) , 761–783. https://doi.org/10.1007/s11192–013–0963–2

Mêgnigbêto, E. (2013b) . Scientific publishing in Benin as seen from Scopus. *Scientometrics, 94* (3) , 911–928. https://doi.org/10.1007/s11192–012–0843–1

Mêgnigbêto, E. (2013c) . Scientific publishing in West Africa : Comparing Benin with Ghana and Senegal. *Scientometrics, 95* (3) , 1113–1139. https://doi.org/10.1007/s11192–012–0948–6

Mêgnigbêto, E. (2015) . Effect of international collaboration on knowledge flow within an innovation system : A Triple Helix approach. *Triple Helix: A journal of university–industry–government innovation and entrepreneurship, 2* (1) . https://doi.org/10.1186/s40604–015–0027–0

Mêgnigbêto, E. (2016) . *Research and innovation in West Africa : An informetric analysis within the framework of the Triple Helix model* [Doctoral dissertation, Universiteit Antwerpen] . https://repository.uantwerpen.be/docman/irua/c26594/135461.pdf

Mêgnigbêto, E. (2021) . Science in West Africa after the first regional STI policy : A global view (2011–2020) . *Journal of scientometric research, 10* (3) , 380–390. https://doi.org/10.5530/jscires.10.3.56

Muchie, M., & Patra, S. K. (2020) . China– Africa science and technology collaboration : Evidence from collaborative research papers and patents. *Journal of Chinese Economic and Business Studies, 1*8 (1) , 1–27. https://doi.org/10.1080/14765284.2019.1647004

NEPAD Planning and Coordinating Agency. (2014) . *African innovation outlook II*. NEPAD Planning and Coordinating Agency.

Niger. Ministère du plan. (2017) . *Plan de développement économique et social 2017–2021 : Un Niger renaissant pour un peuple prospère.* Ministère du Plan. http://www.plan.gouv.ne/uploads/documents/PDES–2017–2021.pdf

Nigeria. Federal Ministry of Finance, Budget and National Planning. (2021) . *National development plan 2021–2025 : Volume I*. Federal Ministry of Finance, Budget and National Planning. https://nationalplanning.gov.ng/wp–content/uploads/2021/12/NDP–2021–2025_AA_FINAL_PRINTING.pdf

N´Zué, F. F. (2014) . *Formulating a regional policy for energy and technology/innovation : What role for taxation*? West Africa Institute – Center for European Integration Studies.

OECD. (2015) . *The measurement of scientific, technological and innovation activities : Frascati manual?: Guidelines for collecting and reporting data on research and experimental development* (7th ed) . OECD Publishing. https://ec.europa.eu/eurostat/cache/metadata/Annexes/isoc_se_esms_an2.pdf

Onyancha, O. B., & Maluleka, J. R. (2011) . Knowledge production through collaborative research in sub–Saharan Africa : How much do countries contribute to each other´s knowledge output and citation impact?. *Scientometrics, 87* (2) , 315–336.

Organisation of African Unity. (1980) . *Lagos plan of action for the economic development of Africa : 1980–2000*. Organization of African Unity.

Resolution on the division of Africa into five regions, Pub. L. No. CM/Res. 464 (XXVI) (1976) . https://undocs.org/fr/A/RES/70/1

Ossenblok, T. L., Verleysen, F. T., & Engels, T. C. E. (2012) . Patterns of co–authorship in journal articles in the social sciences and humanities (2000–2010) . In E. Archambault, Y. Gingras, & V. Larivière (Eds.) , *Proceedings of STI 2012 Montréal* (Vol. 2, p. 640–650) . Science–Metrix; Observatoire des Sciences et

Technologies.

Ossenblok, T. L., Verleysen, F. T., & Engels, T. C. E. (2014) . Co–authorship of journal articles and book chapters in the social sciences and humanities (2000– 2010) . *Journal of the Association for Information Science and Technology, 65* (5) , 882–897. https://doi.org/10.1002/asi.23015

Schneider, J. W. (2010) . *Bibliometric research performance indicators for the Nordic countries : A publication from the NORIA–net "The use of bibliometrics in research policy and evaluation activities"* . Nordic Council of Ministers (NordForsk) . http://norden.diva–portal.org/smash/get/diva2:707816/FULLTEXT01.pdf

Senegal. Gouvernement du Sénégal. (2018) . *Plan national Senegal émergent*. Gouvernement du Sénégal. https://www.un–page.org/files/public/plan_senegal_emergent.pdf

Sierra Leone. Government of Sierra Leone. (2018) . *Medium–term National Development Plan (MTNDP) 2019–2023*. Government of Sierra Leone. http://moped.gov.sl/Development–Plan/MTNDP

Sooryamoorthy, R. (2020) . *Science, policy and development in Africa?: Challenges and prospects*. Cambridge University Press.

Taylor, T. A. (1991) . *Organization and structure of national agricultural research systems in Anglophone sub–Saharan Africa*. International Service for National Agricuitural Research. https://pdf.usaid.gov/pdf_docs/PN–ABH497.pdf

The Gambia. Government of The Gambia. (2018) . *The Gambia national development plan (2018–2021)* . Government of The Gambia. https://ndp.gm

Togo. Gouvernement du Togo. (2018) . *Plan national de développement (PND) 2018–2022* : Version finale. Gouvernement du Togo. https://en.unesco.org/creativity/sites/creativity/files/qpr/pnd_final.pdf

Toivanen, H., & Ponomariov, B. (2011) . African regional innovations systems : Bibliometric analysis of research collaboration patterns 2005–2009. *Scientometrics, 88* (2) , 471–493.

UNESCO. (1974) . *National science policies in Africa : Situation and future outlook—Politiques scientifiques nationales en Afrique : Situation et perspectives*. UNESCO. http://unesdoc.unesco.org/images/0000/000069/006958mo.pdf

UNESCO. (1986) . *Comparative study on the national science and technology policy–making bodies in the countries of West Africa*. UNESCO. http://unesdoc.unesco.org/images/0007/000712/071225eo.pdf

UNESCO. (2015) . *UNESCO science report : Toward 2030*. UNESCO.

UNESCO. (2021) . *UNESCO science report*. UNESCO Publishing.

United Nations Economic Commission for Africa. (2014) . *African science, technology and innovation review 2013*. UNECA.

Wagner, C. S., Park, H. W., & Leydesdorff, L. (2015) . The continuing growth of global cooperation networks in research : A conundrum for national governments. *PloS one, 10* (7) , 1–15. https://doi.org/10.1371/journal.pone.0131816

White, H. D., & Griffith, B. C. (1981) . Author cocitation : A literature measure of intellectual structure. *Journal of the American Society for Information Science, 32* (3) , 163–171.