Journal of Scientometric Res. 2021; 10(3):380-390
http://www.jscires.org

Research Article

Science in West Africa after the First Regional STI Policy: A Global View (2011-2020)

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ABSTRACT
The West African countries adopted in 2012 a five-year STI policy document that should have helped States to master all science fields required for the emergence of a scientific community able to compete and exchange with the best research teams worldwide. This paper aims at measuring the scientific productivity of West Africa after the first regional science, technology and innovation policy and compared to the period 2001-2010. West African countries' scientific data were collected from Web of Science and analysed with regard to the annual production, the total production, growth rate, relative growth index, growth index, international collaboration rate, partner countries and their shares. Over the decade 2011-2020, the region produced more than three times its output over the decade 2001-2010. The international collaboration rate is still higher. The major partner countries are the same as over the previous decade, either in the world or on the African continent. Nigeria is still the local giant with more than half of the regional output; it is followed by Ghana, Senegal and Burkina Faso. The dynamics of production are not the same at country level. West African scientific production is growing more rapidly than the one of the World. Within the region, not all countries have the same volume of production or the same growth speed. Nigeria by far is the local giant, however Ghana is the one that imparts production speed to the region. Taken into account the skewness of the scientific production per country, the study proposes in-depth analysis of the 15 countries grouped in five clusters as follows: small producers (8 countries), lower intermediate producers (3 countries), upper intermediate producers (2 countries), higher producer (1 country) and highest producer (1 country).

Keywords: Scientific research, Science, Technology and innovation, Innovation system, West Africa, ECOWAS.

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Received: 31-07-2020
Revised: 04-02-2021
Accepted: 08-11-2021
DOI: 10.5530/jscires.10.3.56

INTRODUCTION

Science, technology and innovation are recognized as essential means to boost development, so that at any level, policies are adopted to make them contribute to economic growth and social welfare. The Sustainable Development Goals by the United Nations General Assembly[1] assign to the 9th goal to "build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation" and targets (in its point 9.5) to "enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending". At the African continent level, the Constitutive Act of the African Union,[2] the recent Agenda 2063[3] and the resulting Science, technology and innovation strategy for Africa (STISA-2024),[4] the Lagos plan of action[5] and the Africa's science and technology consolidated plan of action,[6] all, underline the role of science, technology and innovation in African development. In 2012, the West African countries, members of the Economic Community of the West African States (ECOWAS, see *Appendix 1*) adopted a five-year science, technology and innovation policy, the ECOWAS Policy on Science and Technology (ECOPOST)[7] with the target of helping 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.

Both regional and international institutions, as well, encourage individual countries too to establish a formal science, technology and information policy; some of the West African did it, but others not (Appendix 2). However, the majority of the African countries are still facing basic social and economic needs like access to food, education and health services or water and sanitation services. Most of these countries are the poorest of the world and are still under international financial assistance, heavily indebted and classified within the bottom

Appendix 1: African countries per region.[48]1

West Africa	East Africa	Southern Africa	Central Africa	Northern Africa
1. Benin	1. Comoros	1. Angola	1. Burundi	1. Algeria
2. Burkina Faso	2. Djibouti	2. Botswana	2. Cameroon	2. Egypt
3. Cape Verde	3. Eritrea	3. Lesotho	3. Centre African Republic	3. Libya
4. Cote d'Ivoire	4. Ethiopia	4. Malawi	4. Chad	4. Mauritania
5. Gambia (The)	5. Kenya	5. Mozambique	5. Congo	5. Morocco
6. Ghana	6. Madagascar	6. Namibia	6. Congo (Democratic Republic)	6. Sahrawi Republic
7. Guinea	7. Mauritius	7. South Africa	7. Equatorial Guinea	7. Tunisia
8.Guinea Bissau	8. Rwanda	8. Swaziland	8. Gabon	
9. Liberia	9. Seychelles	9. Zambia	9. Sao Tome and Principe	
10. Mali	10. Somalia	10. Zimbabwe		
11. Niger	11. South Sudan			
12. Nigeria	12. Sudan			
13. Senegal	13. Tanzania			
14. Sierra Leone	14. Uganda			
15. Togo				

1 The countries list was updated on changes; the last version is provided by the African Union Commission [49].

Appendix 2: Status of West African countries regarding the existence of an explicit STI policy (adapted from Mêgnigbêto [41]).

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

classes of international development indicators whatever the sector is, though endowed with natural untapped resources.[8]

Studies related to the state of science, technology and innovation in Africa are growing. Either, they deal with group of countries (including the whole continent)[9-14] or individual countries.[15,16] The share of the whole African continent to the world knowledge production is negligible though it is trending upwards.[9,10] In 2005, UNESCO[17] asserted that The Netherlands, on its own, produces scientific publications annually more than all the African countries taken together; the African Union noticed that "The output of the African Union (AU) is relatively small, and similar to that of single European countries"[12] and illustrated that the whole Africa's scientific output in Scopus in 2005 "was about the same size as that of Switzerland, Sweden and Poland".[12]

According to the ECOPOST,[7] Member States have researchers in quality in universities and research centres, but their number is insufficient; besides, the contribution of science technology and innovation to economic development of countries and the region is very limited and invisible due to a long list of problems many studies underlined[4,18] among which (i) lack of coordination between research programs and research activities, (ii) lack of human and financial resources and equipment, (iii) insufficiencies or inadequacies of funding and equipment.

The West African scientific output over the period 2001–2010 were studied.[19,20] The region's annual output increased linearly. Nigeria, the largest country of the region and also one of the biggest African science producers, on its own, outputs half the West African total production. *Medicine and Health Sciences* and *Natural sciences* are the main fields of output. The comparison of the region with the BRICS revealed that West Africa performs less than these countries taken individually:[19] with respect to the total scientific production over the period 2001–2010, West Africa stands the last position; with regard to the percentage of citable documents, the region is ranked behind South Africa, India, Brazil and China, but in front of Russia; West Africa depends more on international collaboration. BRICS countries and West Africa share three

partners among the top five, namely USA, UK and Germany. However, West Africa depends more on these three countries than the others. Even though scientific output reported to total population size is considered, West Africa is still at the rear.

This paper aims at measuring the scientific productivity of the ECOWAS after the first regional science, technology and innovation policy; it addresses the following three research questions: 1) How does the scientific research landscape in West African countries look like after the ECOPOST? 2) How does West African science output over the decade 2011-2020 compare to that of the previous decade 2001-2010 at the regional level? and 3) How does West African countries' scientific output over the decade 2011-2020 compare to that of the previous decade 2001-2011? It is organised as followed: section1 introduces the subject and formulates research questions and objectives; section 2 describes data and methods; section 3 analyses data; section 4 discusses the findings and section 5 summaries and concludes.

The ECOWAS and the ECOPOST

The Economic Community of the West Africa States (ECOWAS) is an African regional economic integration organization grouping together 15 Western African countries, in alphabetical order: Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo. The ECOWAS was established with the Treaty of Lagos[21] signed on 28th May 1975 in Lagos. The Treaty was revised in 1993[22] to enable the region to face new challenges. The organization aims at promoting economic cooperation and integration and regional security that should lead to an economic and monetary union through a complete integration of the economies of Member States. The end of these aims is to "raise the living standards of its peoples, and maintain and enhance economic stability, foster relations-among Member States and contribute to the progress and development of the African Continent" (Article 3 of the Revised Treaty).

Article 27 of the ECOWAS Revised Treaty[22] clearly spells out that Member States shall ensure proper application of science and technology to the development of agriculture, transport and communications, Industry, health and hygiene, energy, education and manpower and the conservation of the environment, meaning that research should serve other sectors to develop and thus contribute to economic growth and social welfare. In 2007, the ECOWAS Commission created within the Office of the Commissioner in charge of 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 Policy on Science and Technology (ECOPOST) and its action plan[7] were adopted by the Authority of Heads of State and Government on 29 June 2012.[23] The ECOPOST addresses 12 thematic areas: (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 science and technology: data, statistics and indicators; (j) gender, science and technology; (k) E-governance and Internet massification; and (l) transfer of technology and technology watch.[24]

The ECOWAS countries in particular have common hindrances, includinf[7,18,24–28] i) insufficient funding and equipment, ii) lack of motivation of personnel, iii) lack of explicit science, technology and innovation policy in some countries, iv) inexistence of a regional database on publications, vi) lack of well-informed and organized policy research institutions and advisory bodies to help identify key priority areas where countries may invest their limited resources and set clear and measurable targets, vii) lack of dynamism in STI policies policy design, development and implementation, viii) lack of assessments, monitoring and evaluation of the impact of policy actions, iv) lack or absence of interactions between innovation actors, and, x) non-involvement of universities and research centres to the establishment of STI policy, plan or strategies.

SUBJECTS AND METHODS

From the Web of Science, we searched on 28th February 2020 for all documents with at least one author with a home address in any of the 15 countries of West Africa published between 2011 and 2020 included. The following databases were selected from the Web of Science Core Collection: Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI), Conference Proceedings Citation Index-Science (CPCI-S), Conference Proceedings Citation Index-Social Science and Humanities (CPCI-SSH), Emerging Sources Citation Index (ESCI)[1]. The search expression was (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

1 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.

cu=senegal or cu=sierra leone or cu=togo) and py=2011-2020. Even though papers have studied the regional output over the period 2001-2010, we executed the same search expression for that period[2], to avoid any bias in our analyses, especially in relation with the selected databases by other studies. Then, we used the *Analyze results* option of Web of Science to obtain results presented hereby.

RESULTS

Regional diachronous analysis

Over the period of study (2011-2020), the West African region produced around one hundred thousand papers[3]. The repartition of number of papers per year is given in Table 1 and plotted in Figure 1; it reveals that the region's output regularly increased over the period. The production is best fitted by a linear function of which equation is y = 1,286.3t + 2,895.3 where y is the number of papers and t the period of time (t = 1 in 2011 and R^2 = 0.93); this means that each year of the considered period, West Africa is expected to produce 1,286 additional papers as compared to the previous year.

2 (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=2001-2010.

3 Because the year 2020 did not end yet, the output of the region for that year was estimated.

Table 1: Annual scientific production, growth rate and relative growth rate of ECOWAS from 2011 to 2020.

Year	Output	Growth rate	Relative growth index
2011	5,307	-	100
2012	5,397	1.70	101.70
2013	5,929	9.86	111.72
2014	6,569	10.79	123.78
2015	9,987	52.03	188.19
2016	10,698	7.12	201.58
2017	12,703	18.74	239.36
2018	13,437	5.78	253.19
2019	14,598	8.64	275.07
2020	15,758[3]	7.95	296.93
Total	100,774	-	-

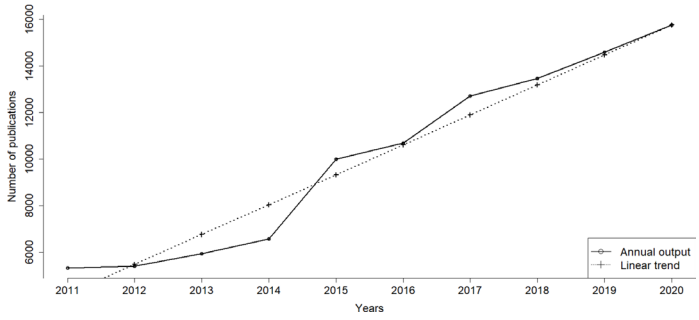

Figure 1: Annual scientific production of ECOWAS from 2011 to 2020.

We computed two indicators that measure the speed of production: the growth rate and the relative growth index. The growth rate is the extent to which the production grows between two periods of time, here within an interval of one year. The relative growth index is the production of a specific year divided by the production of the year considered as reference (2011 is this study); it measures the speed output is growing compared to the output of the reference year. Table 1 gives the growth rates and the relative growth indexes of the West African science over the period 2011 to 2020. It shows that the growth rate in 2015 is the highest (more than 50%) meaning that from 2014 to 2015, there is a shift in the structure of the production of science in West Africa. This shift is also noticed in Figure 1 where a sudden move is recorded on the curve.

As far as the relative growth index is concerned, it slowly increases at the beginning of the period and reaches 123% in 2014; it then rises to 188% in 2015 and 300% in 2020. This sudden growth stems from the high growth rate in the year 2015. This means, for example, that in 2016, West Africa produces twice its total output of 2011 (this year being considered as period of reference, basis=100) and that in 2020, the region produces three-fold its output at the reference year. The comparison to the period 2001-2010 shows that West Africa produces twice more in 2011-2020 (both growth rate and growth index).

In summary, West Africa 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.

Synchronous analysis at region and country level

Table 2 ranks West African countries by their scientific output over the period 2011-2020. Nigeria stands out with more than half the region production; it is followed by Ghana (18.30%); on their own, these two countries authored more than 7 papers out of 10 produced by scientists with a home address in West Africa. Senegal, ranked third, comes far behind with less than half the production of Ghana (7%), followed by Burkina Faso (5.3%). Each of the eleven remaining countries has a share lower than 5% of the regional output. These data show that the distribution of scientific output within member countries is much skewed. If the Gambian production, the median one, is considered as unit, Nigeria produced 27.84 units, Ghana 9.36, Senegal 3.61, etc. (Figure 2). This ranking of the West African countries by their total scientific output is the same as the one by UNESCO[28] based on data from Web of Science and the one by the African Observatory of Science,

Table 2: **Scientific production of West African countries over the period 2011-2020.**

Rank	Countries	Number of papers	% of the regional output	Production with The Gambian output as unit
1	Nigeria	46,750	54.50	27.84
2	Ghana	15,697	18.298	9.35
3	Senegal	6,061	7.065	3.61
4	Burkina Faso	4,561	5.317	2.72
5	Benin	3,807	4.438	2.27
6	Cote Ivoire	3,618	4.218	2.15
7	Mali	2,566	2.991	1.53
8	Gambia (The)	1,679	1.957	1.00
9	Niger	1,478	1.723	0.88
10	Togo	1,160	1.352	0.69
11	Sierra Leone	1,092	1.273	0.65
12	Guinea	951	1.109	0.57
13	Liberia	559	0.652	0.33
14	Guinea Bissau	467	0.544	0.28
15	Cape Verde	294	0.343	0.18

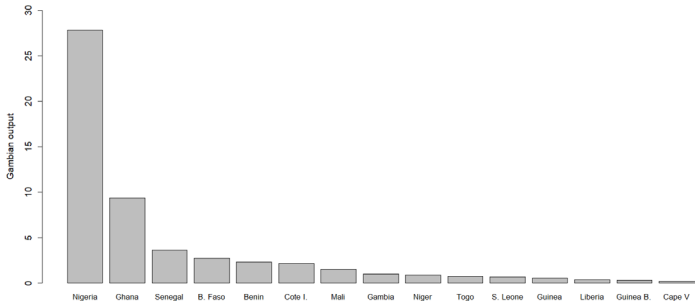

Figure 2: West African countries scientific production over the decade 2011-2020, with the Gambian production considered as unit.

Technology and Innovation[12] based on data collected from Scopus; however there is a little difference with the ranking given in Mêgnigbêto[16,20] with data obtained from Web of Science and Scopus where Cote d'Ivoire ranked the 5th place and Benin the 6th one.

Because, analyses are synchronous, we did not compute growth rate, but relative growth index, and we introduced the growth index which is computed with data from a geographic area as reference (Table 3) and measures how speedy the production grows as compared to that of the area of reference. It appears that while the world production grows only of 18% in 2011-2020 as compared to 2001-2010, Africa triples its output between the two periods; as a consequence, Africa published 2.66 times faster than the world (growth index/ world = 266%). All Member States have a relative growth index greater than 100% meaning that each produces more over the period 2011-2020 as compared to the period 2001-2010. However, the speed of production shows variations among countries: only few countries have a growth index (the region considered as reference) greater than 100, expressing that their production grows faster than the one of the region: Ghana (137%), Sierra Leone (246%), Guinea (318%), Liberia (318%) and Cape Verde (167%); the remaining countries produces at a lower speed than that of the region.

Table 3: **Growth indexes and relative growth indexes of West African scientific output (2011-2020).**

Country/ Geographic area	Number of papers (2001-2010)	Number of papers (2011-2020	Relative growth index[1]	Growth index/ World[2]	Growth index/ Regional[3]
World	4,619,523	5,436,451	118	100	
West Africa	31,904	100,000	313	266	100
Nigeria	17,166	46,750	272	231	87
Ghana	3,645	15,697	431	366	137
Senegal	2,704	6,061	224	190	72
Burkina Faso	1,884	4,561	242	206	77
Benin	1,394	3,807	273	232	87
Cote Ivoire	1,749	3,618	207	176	66
Mali	1,259	2,566	204	173	65
Gambia (The)	1,024	1,679	164	139	52
Niger	625	1,478	236	201	75
Togo	455	1,160	255	217	81
Sierra Leone	140	1,092	780	663	249
Guinea	252	951	377	321	120
Liberia	56	559	998	848	318
Guinea Bissau	228	467	205	174	65
Cape Verde	56	294	525	446	167

In summary, the distribution of papers among countries shows that the region's science production is much skewed: few countries produce the majority of publications. Some countries double their production as compared to their output over the period 2001-2010, other triple, etc. Even though some smaller producers have a very high speed of production, the region's speed of production is imparted by Ghana and Nigeria, the top-two producers with a growth rate equal to 3 and 4 respectively.

International collaboration

Over the 100,383 publications attributed to West Africa, 49,729 (49.83%) are written by authors with addresses in West Africa only, which is about the half. In other words, one half of the West African countries publications (50.47%) are

co-authored with at least one non-West African country. Table 4 provides the list of 24 partner countries with at least 1% share. At the top are USA, UK, France and Germany in this order). The first African country, ranked 5th, is South Africa; it is followed by Kenya (14th) and Cameroun (20th).

Institutional actors

Over the 41 thousand institutions co-authoring West African papers, Table 5 lists only institutions (22) with at least 1% share. They are based mainly in Nigeria; then, come 2 institutions in Ghana (University of Ghana and University of Cape Coast), 1 in Senegal (Université Cheick Anta Diop) and 1 in Benin (Université d'Abomey-calavi). One may notice that neither Burkina Faso ranked 4th nor Cote d'Ivoire ranked 6th by the total production have institutions appearing in this table. This expresses that the two countries are best ranked at country level, but their production is split among home institutions so that no institution from them could compete at the regional level in terms of share. More globally, Nigeria dominates the region's scientific output at both country and institution level as well.

As far as non-West African institutions are concerned, UK, France and USA are the main partners of West Africa (Table 6). The only one African institution appearing in the top is based in South Africa (University of Cape Town), 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 Western World of which 5 from UK, 4 from USA and 5 from France. Not only are the main partner countries out of African, but the main institutional partners are out of Africa also.

Specialisation fields

Based on the concordance table provided by Clarivate Analytics.[29] Web of Science's categories were mapped with the Frascati Manual Fields of Science;[30] then the West African output per science field were computed. It comes out that the region produced mainly in *Medical and Health Sciences* (44.34%), followed by *Natural Sciences* (35.63%),

Table 4: Partner countries of West Africa and their percentage shares.

Rank	Countries	Percentage share
1	USA	15.65
2	UK	10.45
3	France	8.88
4	South Africa	7.84
5	Germany	4.41
6	China	4.11
7	Australia	3.98
8	Malaysia	3.64
9	Switzerland	3.33
10	Canada	3.23
11	Netherlands	2.87
12	Belgium	2.81
13	India	2.79
14	Kenya	2.3
15	Italy	2.18
16	Spain	1.93
17	Papua New Guinea	1.93
18	Brazil	1.72
19	Sweden	1.67
20	Cameroon	1.64
21	Japan	1.63
22	Denmark	1.54
23	Scotland	1.47
24	Uganda	1.39
25	Tanzania	1.24
26	Thailand	1.13

Table 5: Top West Africa-based science producers (2010-2020, share ≥ 1%).

Rank	Institution	Country	Share (%)
1	University of Ibadan	Nigeria	7.077
2	University of Ghana	Ghana	6.294
3	University of Nigeria	Nigeria	4.929
4	Kwame Nkrumah University of Science and Technology	Ghana	4.406
5	Obafemi Awolowo University	Nigeria	3.780
6	University of Lagos	Nigeria	3.594
7	Covenant University	Nigeria	3.013
8	Université Cheikh Anta Diop	Senegal	2.850
9	University of Ilorin	Nigeria	2.644
10	Ahmadu Bello University	Nigeria	2.604
11	Federal University of Technolology Akure	Nigeria	2.063
12	Université d'Abomey-Calavi	Benin	1.915
13	University of Benin	Nigeria	1.813
14	University of Agriculture Abeokuta	Nigeria	1.541
15	University of Cape Coast	Ghana	1.478
17	Bayero University	Nigeria	1.271
18	University of Calabar	Nigeria	1.271
19	Lagos State University	Nigeria	1.268
20	University of Port Harcourt	Nigeria	1.262
21	Nnamdi Azikiwe University	Nigeria	1.169
22	Ladoke Akintola University of Technology	Nigeria	1.053

Table 6: Top institutional information producers partner 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
7	University of California	USA	1.609
8	Institut National de la Santé et de la Recherche Médicale	France	1.556
9	University of Witwatersrand	South Africa	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 Africa	1.271
14	Johns Hopkins University	USA	1.218
15	University of Oxford	UK	1.159
16	US Center for Disease Control Prevention	USA	1.077
17	National Institute of Health	USA	1.057

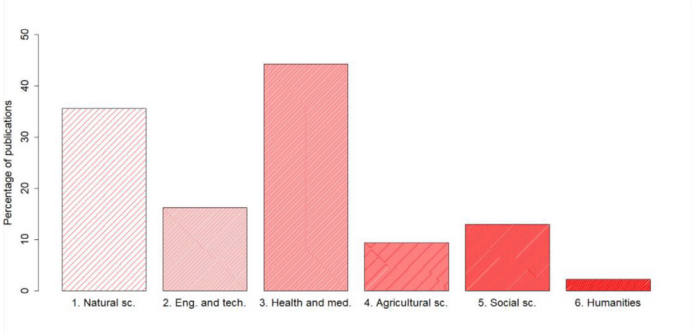

Figure 3: West African scientific output per Frascati Manual Fields of Science.

Engineering and Technology (16.17%); *Social Sciences* are ranked 4th with 12.93%, followed by Agricultural science 9.39% and Humanities at the rear (with 2.21%) (Figure 3).

Figure 4 presents the specialisation index of the West African region with reference to the Word and the African continent respectively. It shows that the region displays the same pattern towards these two references: it overspecialised in *Agricultural sciences* (indexes 2.70 and 1.54 respectively), *Health and medical sciences* (indexes 1.27 and 1.33 respectively) and *Social sciences* (indexes 1.10 and 1.22 respectively) but under specialised in *Natural sciences* (indexes 0.86 and 0.78 respectively), *Engineering and technology* (indexes 0.65 and 0.66 respectively) and *Humanities* (0.34 and 0.66 respectively).

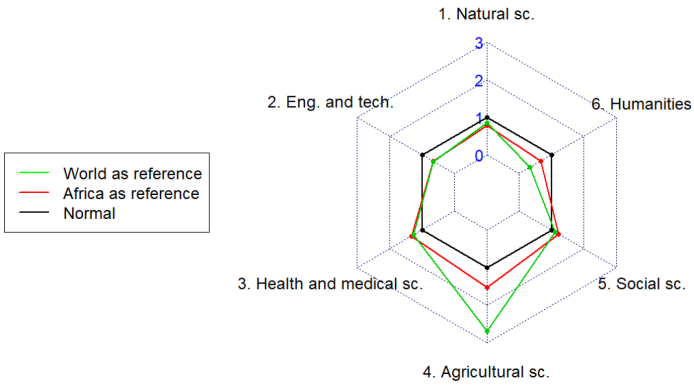

Figure 4: Specialisation indexes of the West African region (2011-2020).

DISCUSSION

The paper draws the landscape of scientific publishing in West African countries with a focus on the decade 2011-2020. It reveals that i) West Africa science production triples as compared to the previous decade; ii) the production growth varies over countries; iii) the region is still depending on abroad to produce knowledge and iv) the region specialises in *Health and medical sciences* and *Agricultural sciences*.

West Africa triples its output over one decade

As compared to the production of the region over the period 2001-2010, the scientific output of West Africa triples over the period 2011-2020; this expresses a significant growth in research activities and, probably, a change in the database coverage. Indeed, databases regularly assess new journals or existing ones to cover them, inducing growth in publications;[31] in the case of the European Nordic countries for example, Schneider[32] stated that indexing new journals explains 60% of the rise in the number of publications. On the other hand, the growth in doctoral students number noticed by UNESCO[28] may have induced increase in research activities resulting in growth of number of publications.

This growth index of West Africa (both with the world and Africa and reference) is higher than 100, meaning that the region's science grows faster than the one of the World on the one hand, and the one of Africa on the other hand; if the continent's share to the world knowledge production is less than 1% in 2005, a trending upward was recorded starting of the year 2000 so that the continent doubles its share around 2010.[9,10,12] With data we collected from Web of Science, Africa authors 2.56% of the world production over the period 2011-2020; however, disparities are recorded between regions share to the continent scientific production: the biggest producer is the Northern Africa (48.18%), followed by Southern Africa (31.45%), West Africa (13.84%), East Africa (12.16%) and Central Africa (2.9%) at the rear. Note that the sum of regions' shares is greater than 100% due to intraregional collaboration.

Table 7 presents the growth index of African regions with various geographic areas as reference. It shows that all African regions have produced speeder than the world and the West Africa has the highest speed; as a consequence, the growth indexes of the continent and its regions with West Africa as reference are lower to 100.

At individual countries level, the relative growth index varies, expressing different national dynamics. If Nigeria and Ghana, the top-two producers display a value around 3 and 4, some of the lower producers display higher values. This is the case of Sierra Leone (780%), Guinea (377%), Liberia (998%) and Cape Verde (525%) which have a growth index higher than the one of the region. These countries have probably a weak research infrastructure, become aware of it and engage process to improve it in order to face development challenges.[7,33]

Table 7: Growth indexes of scientific production in Africa and its regions (2011-2020).

	Geographic area as reference						
Geographic area	World	Africa	Northern Africa	East Africa	Southern Africa	Central Africa	West Africa
World	100	51	49	50	61	56	47
Africa	194	100	94	98	119	109	91
Northern Africa	206	106	100	104	126	116	96
East Africa	199	102	97	100	122	112	93
Southern Africa	163	84	79	82	100	92	76
Central Africa	178	91	86	89	109	100	83
West Africa	214	110	104	108	131	121	100

Distribution of publications number among countries is much skewed

According to raw data presented above, Nigeria is the biggest science producer in the region, with more than half the total regional output, i.e., Nigeria, on its own, produces almost equally as the remaining 14 countries. A number of factors give such advantages to this country: the seize of its population, its economic weight in the region (nearly 70% of the regional GDP in 2016,[34] more than half the industries installed in the region[8]) and as consequence of these two factors, the number of universities (more than half the number of public university in West Africa,[7]) the number of students, the number of researchers (70% of the regional numbers of researchers[7]) and the GERD. However, when the number of inhabitants is taken into account, Nigeria is no longer at the top position, but ranked 7th; The Gambia comes first, followed by Ghana and Cape Verde (Table 8). Note that among the 15 West African countries, only Ghana and Cape Verde are categorized in *Medium human development* group by the United Nations Development Programme in 2019 and all the remaining in the lower category, the *Low human development group*.[35]

Table 8: Number of papers per million inhabitants and some social statistics on West African countries.

Country	Population (in millions)[4]	Number of papers	Papers / million inhabitants	GERD as % GDP[5]	Researchers / million inhabitants [8]	IDH [6]	
						Rank (World/ West Africa)	Value
Gambia (The)	2.4	1,679	699.58	0.07 (2018)	632.61 (2018)	174/8	0.466
Ghana	31.1	15,697	504.73		122.89 (2015)	142/2	0.596
Cape Verde	0.6	294	490.00		173.65 (2014)	126/1	0.651
Senegal	16.7	6,061	362.93	0.57 (2015)	639.89 (2015)	166/6	0.514
Benin	12.1	3,807	314.63			163/4	0.520
Guinea Bissau	2	467	233.50			178/11	0.461
Nigeria	206.1	46,750	226.83			158/3	0.534
Burkina Faso	20.9	4,561	218.23	0.70 (2017)		182/13	0.434
Togo	8.3	1,160	139.76	0.27 (2014)	64.49 (2018)	167/7	0.513
Cote d'Ivoire	26.4	3,618	137.05	0.1 (2016)		165/5	0.516
Sierra Leone	8	1,092	136.50			181/12	0.438
Mali	20.3	2,566	126.40	0.3 (2017)	78.39 (2017)	184/14	0.427
Liberia	5.1	559	109.61			176/10	0.465
Guinea	13.1	951	72.60			174/8	0.466
Niger	24.2	1,478	61.07		49.07 (2013)	189/15	0.377

Not all countries produce scientific data on regular basis, so they are scarce. The Gross Expenditure in Research and Development (GERD) measured as percentage of the Gross Domestic Product and the number of researchers are given for the most recent years in Table 8. The highest value (0.7) is registered for Burkina Faso in 2017; it is however far from the target of 1% African countries committed on in many policy documents [e.g.5] These data show that West African countries, on the one hand, are still far from the target of 1% they committed to early in 1980 with the Lagos plan of action[5] and renewed in many other policy documents, and on the other hand, lack researchers.[12–14,20,28,36,37]

The region is still highly depending on abroad

The international collaboration rate of the region is around 50% meaning that the region produces at least half its papers with non-West African countries. Compared to the period 2001-2010, USA, France and UK are still the top-three partner countries; however, France moves back and ranked 3rd over the period 2011-2020, after UK ranked 2nd. Colonial ties or cultural link explains the strength of the relations.[10,20] South Africa is becoming a major scientific actor on the African continent; ranked 5th before over the period 2001-2010, it is positioned 4th for the second period, probably due to recent cooperation agreements this country signed with some Member States in West Africa.[28] China that did not appear in to top-10 partners in 2001-2010 is ranked 6th now; note that the China-Africa collaboration is increasing and is likely to grow in the coming years as China is emerging as a leading global research hub in the world.[40] These ranks may change more rapidly because, Africa seems not to be a reserved field of USA and Western Europe countries any longer; the multiplication cooperation frameworks with periodical high political level summits to yield and monitor agreements with Africa that encourage cooperation in science, technology and innovation (e.g. with Europe, Russia, Japan, China, Turkey, Brazil, etc.) may explain the high collaboration rate and changes in partner countries rankings. On their own, the top-5 partner countries (USA, UK, France, Germany and South Africa) share around 50% of the total production against 40% over 2001-2010; this increase expresses interests of foreign countries to collaborate with African countries but also the dependence of the country to the rest of the World.

The region specialises in Health and medical sciences and Agricultural sciences

Raw data gives advantages to *Health and medical science* and *Natural sciences* fields, in this order; *Agricultural sciences* is ranked 5th after *Engineering and technology* (3rd), *Social sciences* (4th) and before *Humanities* (6th). This findings somewhat is in contradiction with those of Mêgnigbêto[41] where *Agricultural sciences* and *Engineering and technology* have the same share and ranked 3rd and 4th. UNESCO[28] noticed that even though government adopted developments policy where the priority to feed citizens is expressed, agriculture is not the field countries produced enough in.

However, when specialisation indexes are taken into account, the ranking differs: West Africa specialised in *Agricultural sciences* and *Health and medical sciences*; it is neutral in *Social sciences* and *Natural sciences* but under specialised in *Engineering and technology* and *Humanities*. According to Dahoun,[42] countries priorities are feeding people and taking care of their health; moreover, on their independence, countries inherited solid colonial research institutions in these two fields,[7] that explains these specialisation indexes. Besides, Web of science under covers *Social sciences* and *Humanities* in favour of *Natural sciences*, *Health and medical sciences*,[43–45] so the under specialisation may result from bias due to the data source; note that social sciences generally receive the least funding.[46] The under specialisation in *Engineering and technology* originates from the weak share of students in these fields (less than 25% [7]) and, as a consequence, the lower investment of governments in the postsecondary vocational and professional education and training (less than 5% of education budget[47]) and is common to all the sub-Saharan Africa. Table 9 displays that specialisation indexes divide the African continent into two parts: the Northern Africa specialised in *Natural sciences* and *Engineering and technology*, and the Sub-Saharan-Africa (grouping the 4 other regions) under specialised in *Natural sciences* and *Engineering and technology* but specialised in *Health and medical science*, *Agricultural sciences*, *Social sciences* and *Humanities*.

Table 9: Specialisation indexes of African regions and South Africa with Africa as reference (2010-2020).

Fields of Science (Frascati Manual)	West Africa	East Africa	Southern Africa	Central Africa	Northern Africa	South Africa
1. Natural sciences	0.78	0.85	0.95	0.95	1.12	0.98
2. Engineering and technology	0.66	0.43	0.64	0.45	1.47	0.68
3. Health and medical sciences	1.33	1.49	0.90	1.46	0.83	0.83
4 Agricultural sciences	1.54	1.70	0.82	1.20	0.78	0.77
5. Social sciences	1.22	1.06	1.76	0.63	0.37	1.82
6. Humanities	0.66	0.41	1.86	0.46	0.62	4.92

CONCLUSION

This paper gives a global view of the landscape of scientific publication in West Africa over the decade 2011-2020, after the first regional science and technology policy compared to the decade 2001-2010. It reveals that West Africa triples its scientific production expressing a dynamics in research activities in the region. The dynamics is however of different levels depending on the countries: if Ghana and Nigeria, the biggest science producers within the region, triple their outputs, some of the smallest producers multiply their production by more than 5. The international collaboration rate is still as high as over 2001-2010. The top-5 partners are the same as in 2001-2010, but South Africa and Germany interchanged their rank. China now has an appreciative share to the regional output and is becoming a major partner of West Africa.

The distribution of publications among countries is much skewed:, when The Gambia, the median country's output is taken as unit of measurement, Nigeria produced around 27 units, Ghana 9, Senegal around 4, but the smallest producers like Guinea Bissau 0.28 and Cape Verde produced 0.18. Due to the high skewness, country-specific analyses are needed to better understand the weakness and strengths of research and innovation infrastructure at national level and explain the performance of the region. To this order, we propose the division of the 15 countries in 5 clusters as follows: 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.

Some (combined) factors may explain the performance of the region: governments may have allocated more means to science, technology and innovation; Africa has the youngest population that needs education; combined with the trending upwards of life expectancy, African people have opportunities to access high education; in accordance, countries are strengthening and widening their education infrastructures. The fact that the number of doctoral students is increasing is an illustration, favoured by diversification of the number of doctoral schools within the region. Therefore, people have much opportunity to study at home instead of abroad. As a consequence, the cost of doing doctoral studies diminishes, so more people can register. Moreover, the development of distance learning may have offered opportunities to stay home and access education in Western countries, both in fields covered or not covered by the home educational system.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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(FOOTNOTES)

1. Relative growth index of the period 2011-2020 with 2001-2010 as reference.
2. Growth index with the world production as reference.
3. Growth index with the ECOWAS production as reference.
4. Source: UNFPA [38].
5. Source : UNESCO Institute of Statistics [39].
6. Source: UNDP [35].