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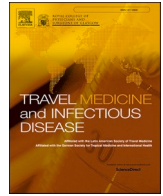
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# Visualization of scientific collaboration and themes for arbovirus disease in the caribbean: A forty-year trend analysis with focus on dengue, Zika and Chikungunya

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## ABSTRACT

**Background:** The (re-)emergence of arboviruses in the Caribbean, and worldwide, is a major public health issue of concern to all scientific research stakeholders. This study aimed to use bibliometric analysis to identify the contribution of Caribbean countries to scientific production regarding the three arboviruses with the greatest impact, namely zika, chikungunya and dengue.

**Method:** Bibliographic data related to arbovirus diseases were collected from three international databases (Web of Science, Pubmed, and Scopus), filtered by Caribbean islands of affiliation. VosViewer was used to identify scientific connections between countries or institutions and to identify research themes.

**Results:** The dataset comprised 1332 indexed articles, with 50% of articles categorized in the top quartile of quality. Cuba was found to lead research on dengue, with a total of 300 articles, and 18 international connections. The USA-Puerto Rico duo was found to be the leader on emerging arboviruses (Zika and Chikungunya), followed by a predominantly French-language cluster (mainland France, Guadeloupe, Martinique). Key research topics were related to clinical presentations, epidemiology, and research on mosquito-borne viruses

**Conclusions:** Co-authorship network analysis on emerging arboviruses revealed the dynamics of collaboration, and provides insights into Caribbean collaborations that deserve to be created and consolidated in case of resurgence of new arbovirus epidemics.

## 1. Introduction

The emergence and re-emergence of arboviruses in the Caribbean, as well as on a global scale, is a major public health issue of concern to all scientific research stakeholders. Arboviruses are a group of RNA viruses that are transmitted by mosquitoes, ticks, or other blood sucking arthropods [1]. The impact of arboviruses, especially those transmitted by *Aedes aegypti*, such as the viruses that cause dengue (DENV), Zika (ZIKV) and Chikungunya (CHIKV), on morbidity and mortality among Caribbean populations remains worrying, and keeps each country in the area on high health alert [2]. Over the last 50 years, the global incidence of DENV has increased 30-fold and affects 100 countries in the tropical and

subtropical regions of the world [3]. DENV counts among the tropical infections recognized as a “priority neglected tropical disease” by the World Health Organization (WHO) [4] and remains the most widespread mosquito-borne viral infection in the world [5]. Speculative estimates project an increase of 2.25 billion between 2015 and 2080 in the number of people at risk of DENV infection [6]. Between 1980 and 2020, more than 1100 million cases of DENV infection were recorded by the Pan-American Health Organization (PAHO) in the Caribbean [7]. CHIKV and ZIKV both emerged recently in the Caribbean, causing large epidemics starting in December 2013 [8] and in May 2015 [9], respectively. The CHIKV epidemic spread through the Caribbean and the entire American continent, resulting in more than one million confirmed

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infections by December 2014 [10]. The number of cases per 1000 inhabitants per year was particularly high for CHIKV between 2013 and 2017 in Montserrat (186), St. Lucia (80), Martinique (71) and Guadeloupe (77). ZIKV is considered an urgent public health problem by the WHO [11]. More than 143,000 cases have been recorded in the Caribbean, with 77 and 98 cases per 1000 inhabitants in Guadeloupe and Martinique respectively in 2016 [9]. The number of arbovirus infections is potentially underestimated, and certainly does not reflect the real rates of infection in the countries concerned, considering access to healthcare among symptomatic persons, the difficulty of obtaining laboratory confirmation for acute cases, and challenges distinguishing ZIKV from other flaviviruses serologically [12].

The continued and increasing frequency of DENV epidemics and emerging arboviruses with high public health impact, such as ZIKV and CHIKV, are garnering growing scientific interest. Several bibliometric studies have been conducted on the major arbovirus diseases, namely ZIKV, DENV [13–16], and CHIKV [17], but few stemmed from Latin America or Caribbean countries [18,19]. In addition, there is a paucity of information regarding the contribution of Caribbean countries to research on arboviruses, although they are exposed to climatic conditions conducive to the propagation of these diseases. Little information is available on the impact and contribution of the scientific production of Caribbean countries at the global level. An analysis of the responsiveness of countries to recent epidemics of emerging arboviruses (ZIKV and CHIKV) and their response to the scientific challenge posed by successive dengue epidemics may provide useful information for the global scientific community. In addition, we lack information about the extent of geographic collaborations of the Caribbean countries, which are mostly low-middle-income or upper-middle-income countries [20] and thus may be required to collaborate with high income countries on

an international scale [21,22]. This kind of analysis could enable us to anticipate constructive and impactful scientific collaborations on arbovirus research in the upcoming years. Thus, it would be of interest to disseminate reliable data on the number of indexed publications on arboviruses from the Caribbean, and regarding trends in the geographical affiliation of the authors. Analysis and visualization tools such as VosViewer have often been used to identify connections between countries or institutions [23–25] or to identify research themes from the keywords used in articles [18,26]. In order to appreciate the dynamics of scientific publication trends on arboviruses, it would also be useful to identify existing and emerging international collaborations between countries within the Caribbean area. The objective of this study was therefore to use bibliometric analysis methods: 1- To identify the contribution of Caribbean countries to scientific production regarding arboviruses, focusing on the three arboviruses with the greatest impact, namely ZIKV, CHIKV and DENV; 2- To describe existing international scientific collaborations, and to observe the dynamics of these collaborations between the two main emerging arboviruses (ZIKV and CHIKV) and DENV.

## 2. Methods

### 2.1. Geographical scope of study

The Caribbean is positioned in both the northern and southern hemispheres. The islands are bordered in the east and north by the Atlantic Ocean with a tropical climate favorable to the propagation of mosquitoes. The term “Caribbean islands” will be used in this article instead of the term “country” because of the differences in independence status between the Caribbean countries. The set of Caribbean islands



Fig. 1. Map of the Caribbean islands

Legend of Fig. 1: Greater Antilles, comprising five islands: Cuba, Jamaica, Cayman Islands, Puerto Rico, and as well as Haiti and Dominican Republic (which are on the same island). Lesser Antilles, comprising 15 Caribbean islands: Antigua & Barbuda, Barbados, Dominica, Grenada, Saint Kitts & Nevis, Saint Lucia, Saint Vincent and the Grenadines and Trinidad and Tobago, Aruba, Anguilla, Curaçao, Guadeloupe, Martinique, and UK and US Virgin Islands (copyright-free, downloaded from: <https://thumbs.dreamstime.com/z/map-caribbean-islands-island-different-country-such-as-cuba-haiti-dominican-republic-bahamas-more-173521805.jpg>).

analyzed in this study includes all the sub-regions of the Caribbean, as shown in Fig. 1, namely:

- Greater Antilles, covering a total area of 207,411 km<sup>2</sup> with a population of about 39 million inhabitants, and comprising five islands: Cuba, Jamaica, Cayman Islands, Puerto Rico, as well as Haiti and the Dominican Republic (which are on the same island, called Hispaniola).
- Lesser Antilles, covering a total area of 14,364 km<sup>2</sup> with a population of about 4 million inhabitants, and comprising 15 Caribbean islands: Antigua & Barbuda, Barbados, Dominica, Grenada, Saint Kitts & Nevis, Saint Lucia, Saint Vincent and the Grenadines and Trinidad and Tobago, Aruba, Anguilla, Curaçao, Guadeloupe, Martinique, and UK and US Virgin Islands.

## 2.2. Search strategy

We performed a bibliometric analysis using the international databases Web of Science (WOS), Scopus and PubMed, for the period from 1980 to 2020 inclusive (41 years). Separate searches were conducted for DENV, CHIKV, and ZIKV combined with all Caribbean islands (see geographic scope of study below). The combinations of different search terms within each database are available in Supplementary File S1. Only Medline indexed articles with an available PMID, known as the PubMed reference number, were considered in the analysis. Publication types included original research articles, reviews, letters, editorials and commentaries.

## 2.3. Standardization of data

Results of each query were downloaded separately and then merged as a single database. All publications containing at least one author affiliated to a Caribbean island (regardless of the author's position in the author list) were selected; however we noted if these authors were in the first or senior author position [27,28]. Each affiliation thus identified in Pubmed was classed by Caribbean island. The search was performed in March 2021.

## 2.4. Bibliometric indicators

Quantitative indicators included the number of publications per virus (DENV, CHIKV, and ZIKV) to measure scientific output of each Caribbean island by type of publication. Performance indicators as measured by Journal Citation Reports (JCR) journal rankings in the WOS for each of their 256 categories helped to analyze the quality of publications [29]. Quartiles of JCR journal ranking were calculated accordingly where Q1 represents the highest quality journals in each category and Q4 the lowest quality. Organization-specific indicators, also known as structural indicators, were used to measure links between publications, organizations, Caribbean islands, authors, and research fields. The analysis of organization-specific indicators was performed using the freely available software VOSviewer (version 1.6.16, <https://www.vosviewer.com/>) using the "association strength" measure as proposed by Van Eck and Waltman. VosViewer was used to map the links, and to identify clusters representing a set of islands with close connections among themselves. The quantification of co-occurrences carried out by the software makes it possible to measure the existing association between several "items", which can be individual authors, keywords, institutions or even countries. The complete dataset was analyzed in VosViewer with one eligibility criterion to be taken into account: the association matrix was measured from links limited to a minimum number of 5 occurrences of a keyword or a country in order to have a better overview of pertinent associations of our dataset. Keywords from the title and abstract were used in VosViewer [30,31]. Data were extracted in XML format from PubMed and analyzed using SAS version 9.4 (SAS Institute Inc., Cary, NC).

## 3. Results

For the evaluation of the contribution of Caribbean islands to the scientific publications on arboviruses, the database searches yielded the following results: 1140 articles were found in Scopus, 1118 in Pubmed, and 880 in WOS. Merging results from all 3 databases, we obtained a dataset of 1332 indexed articles after removal of duplicates. The distribution of the publications across the databases is presented using a Venn diagram in Supplementary File S2.

Concerning the sources of funding indicated in the articles of the databases, only 536 out of 1332 articles (40%) provided information about the funding received.

For the three arboviruses of interest, we observed two profiles of increase in the number of published articles: a steady increase since the 1980s for DENV, and an increase starting in 2015 for CHIKV and 2016 for ZIKV (Fig. 2). There was an increase in the number of articles about CHIKV between 2015 and 2020 from 44 to 221 articles (+402%); from 45 to 281 (+524%) between 2016 and 2020 for ZIKV, and from 738 to 1053 (+43%) for DENV between 2015 and 2020. Regarding the quality of the publications, which refers to the four quartiles of the ranking distribution, the increase in the number of publications in the Q1 category was greatest, with more than 270 articles in Q1, versus 130 in Q2, 33 in Q3 and 63 in Q4 (Fig. 3). Overall, we found a large proportion of articles in the Q1 category over the entire analysis period (1996–2020), representing on average 50% of the total number of articles.

Table 1 shows the ten journals that published the most scientific articles within the analysis. The *American Journal Of Tropical Medicine And Hygiene* is the journal that published the most articles from the Caribbean on DENV, with 102 articles. The top ranked journal among the top ten journals for publications on ZIKV was *PLoS Neglected Tropical Disease*, with 22 articles and 29 articles for CHIKV.

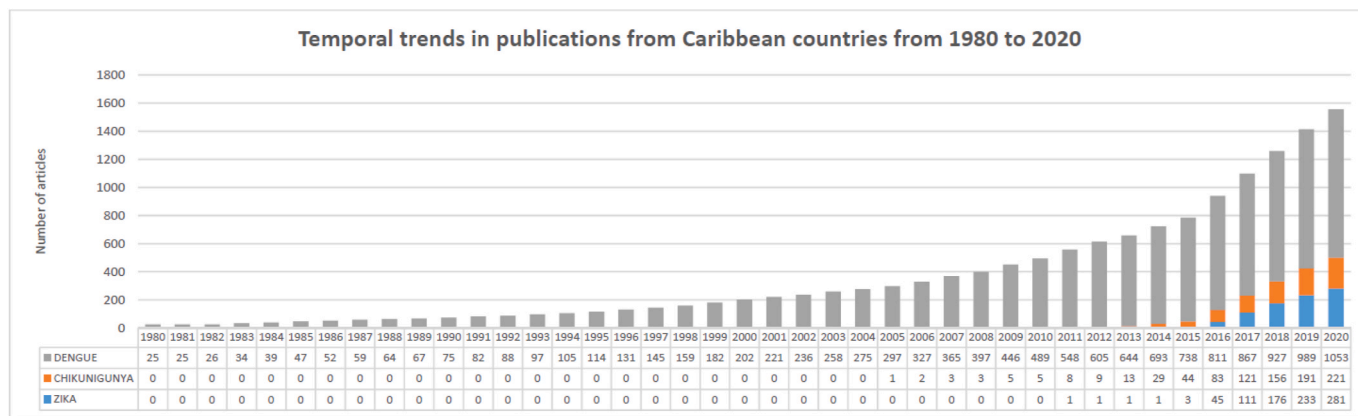
The distribution of publications observed by Caribbean island between DENV and the emerging arboviruses (ZIKV and CHIKV) is shown in Fig. 4. The Caribbean islands selected in this analysis had a minimum of 20 papers published on all three arboviruses. Cuba and Barbados were the two islands with a majority of articles on DENV, with 96% and 92% respectively. Regarding the proportion of articles dedicated to emergent CHIKV or ZIKV, Martinique led the field with 52%, followed by Guadeloupe and Puerto Rico with respectively 32% and 29%.

Among the 1332 articles, we analyzed the first and last authors from each publication: Cuba had the highest number of first authors with 306 (23%), followed by Puerto Rico with 237 (18%) and the USA with 235 (18%) first authors (Fig. 5). Puerto Rico had the highest number of last authors with 258 (19%), followed by Cuba and USA with 250 (19%) each. A complete list of first and last authors' country of affiliation is available in Supplementary File S3.

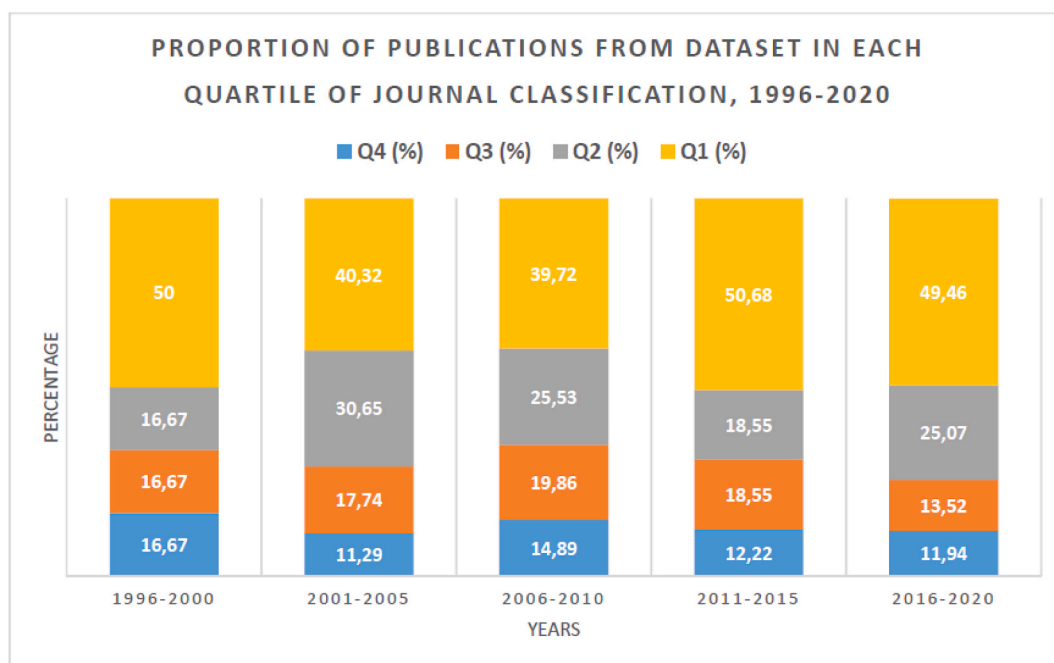
The status of collaborations between the different authors of the 1332 identified articles was evaluated with VosViewer. Regarding DENV, two clusters predominate (Fig. 6A), one comprising Cuban authors with a total link strength of 215 and 18 links with other countries, and a second cluster dominated by Puerto Rico (total link strength: 192 and 15 links) and the USA (total link strength: 332 and 23 links).

We note the presence of a French-speaking cluster (Fig. 6A), with France as leader (total link strength: 122 and 16 links) comprising in particular the French overseas departments (Martinique, Guadeloupe, French Guyana). For CHIKV and ZIKV shown in Fig. 6B, we can distinguish a cluster with the USA (total link strength: 97 and 13 links) and Puerto Rico (total link strength: 55 and 4 links). We noted the presence of a French-speaking cluster (Fig. 6B), with mainland France (total link strength: 87 and 10 links), Martinique (total link strength: 56 and 7 links) and Guadeloupe (total link strength: 53 and 8 links).

To identify the themes to which Caribbean islands have contributed, mapping organized by co-occurrences of keywords available in the dataset for the 3 arbovirus diseases of interest is presented in Fig. 7. Each keyword is represented by a circle, where its diameter and label size are proportional to the number of publications that have the corresponding



**Fig. 2.** Temporal trends in publications from Caribbean countries from 1980 to 2020  
 Legend of Fig. 2: Fig. 2 represents the progression in the number of articles per year from 1980 to 2020, for Dengue (in grey), Chikungunya (in orange), and Zika (in blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)



**Fig. 3.** Proportion of publications from the dataset in each quartile of journal classification, 1996–2020  
 Legend of Fig. 3: Performance indicators: we analyzed the quality of publications, as measured by Journal Citation Reports (JCR) journal rankings in the WOS for each of their 256 categories. Briefly, quartiles are calculated as follows: Let X be the journal rank in the category according to the metric (Journal Impact Factor, Total Citations, etc.); and Y the number of journals in the category. The journal rank is calculated as  $Z = \text{percentile rank}(X/Y)$ . The quartiles of journal rankings are calculated as Q1 ( $0.0 < Z \leq 0.25$ ); Q2 ( $0.25 < Z \leq 0.5$ ); Q3 ( $0.5 < Z \leq 0.75$ ) and Q4 ( $0.75 < Z$ ), whereby Q1 represents the highest quality journals in each category. A harmonic mean of Category Expected Citations was performed for journals that belong to multiple WOS categories.

keyword in their title or abstract. Clusters are a set of keywords linked together included in a map. Several clusters are highlighted, representing the various research themes by arbovirus. Several clusters with common themes across the three arboviruses are identified: the most important one was related to the clinical characteristics of patients and research on the *Aedes aegypti* mosquitoes (in green). For DENV (Fig. 7A), we identified basic research on the pathophysiology of the virus and therapeutic research, and for CHIKV (Fig. 7B), and ZIKV (Fig. 7C) research focused more on diagnostic tests.

#### 4. Discussion

Our study shows that the scientific production in the Caribbean has increased significantly and persistently over the last 40 years in DENV

research, and was particularly striking at the time of the epidemic peaks of ZIKV and CHIKV. The quality of the 1332 articles identified through cross-referencing of three international databases, (Scopus, WOS, Pubmed) was generally high, with most articles in the top quartile of quality according to the Clarivate Journal Citation Reports classification. The distribution of scientific production between DENV and the emerging arboviruses (CHIKV and ZIKV) is well balanced for some Caribbean islands, such as Martinique, Dominican Republic, and Grenada, and very specific, even exclusive as for Cuba, and Trinidad and Barbados. Cuba is undoubtedly the leader in the Caribbean in terms of scientific research on DENV. More globally, Puerto Rico and the USA are very active in terms of publications, especially with higher proportions of authors in last position. The collaborations between the USA and Puerto Rico are naturally very strong and account for the largest number

**Table 1**  
Top 10 journals in terms of number of papers published from the Caribbean.

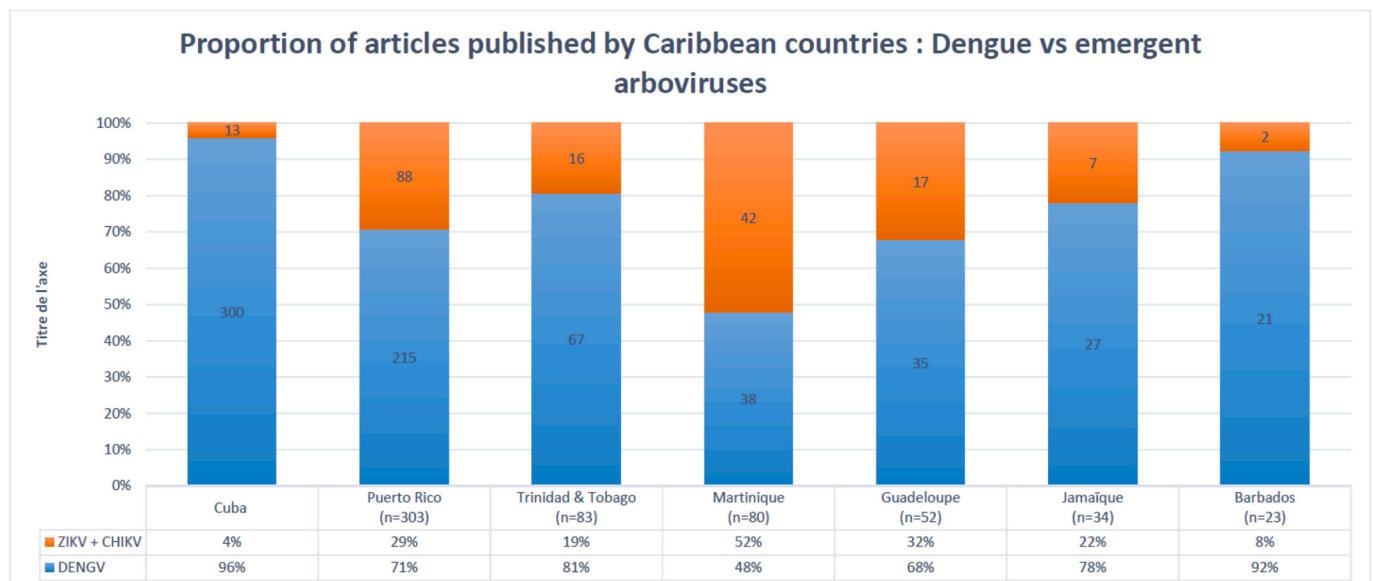
Journal title	Dengue		Zika		Chikungunya		TOTAL	
	n	Rank	n	Rank	n	Rank	n	Rank
American Journal of Tropical Medicine and Hygiene	102	1	7	5	21	2	130	1
PLoS Neglected Tropical Diseases	77	2	22	1	29	1	128	2
Emerging Infectious Diseases	26	4	10	4	9	4	45	3
PLoS One	24	5	4	7	9	4	37	4
Journal of the American Mosquito Control Association	28	3	1	10	3	8	32	5
Revista Panamericana de Salud Publica-Pan American Journal of Public Health	23	6	3	8	11	3	37	6
Puerto Rico Health Sciences Journal	8	9	16	3	7	6	31	7
Acta Tropica	23	6	2	9	4	7	29	8
MMWR-Morbidity and Mortality Weekly Report	4	10	19	2	1	9	24	9
The Lancet	20	8	5	6	1	9	26	10

of collaborations with other Caribbean islands. Research on emerging arboviruses in the Caribbean is mainly oriented around two main axes for emergent arboviruses, namely the clinical characteristics of patients, and research on *Aedes aegypti* mosquitoes, with a third axis for DENV focusing on basic research into the pathophysiology of the virus and therapeutic research.

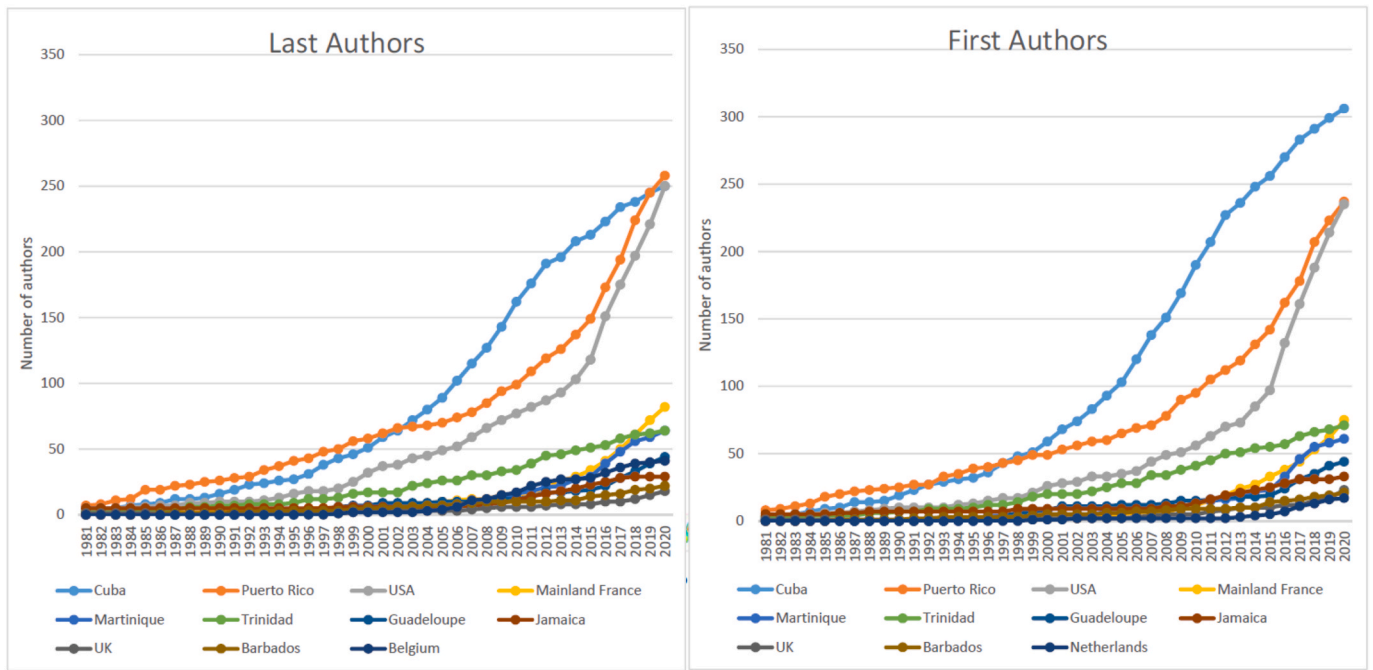
Since the emergence of the ZIKV epidemic in 2015, several consortia have been created at the international level involving Caribbean islands,

e.g. ZikaPlan [32], ZikAlliance [33] and ZikaAction [34], and have contributed to the increase in scientific production on ZIKV disease [35]. Cuba, though classified as an upper middle income country [20], is the most prolific island in the Caribbean and even internationally on DENV research. The collaboration observed between Cuba and the USA on DENV research reinforces the project of a historical rapprochement between the two islands initiated in 2014 and consolidated for the purposes of research on arboviruses during the conference entitled “Exploring Opportunities for Arbovirus Research Collaboration” held in 2016 [36]. We noted few links with Caribbean islands. Indeed, there were only three connections (namely with Trinidad & Tobago, Puerto Rico and Guadeloupe) (Fig. 5A). The strong presence of authors from the United States in research on arboviruses in the Caribbean should also be noted. This can be explained by the considerable investments made, with several hundred million dollars injected into research on arboviruses [37]. This dominance contrasts with the small number of low or middle income Caribbean countries, which are poorly represented, particularly in research on emerging arboviruses (ZIKV and CHIKV), highlighting the commitment of high-income countries to collaborate with countries that could have academic talent [38].

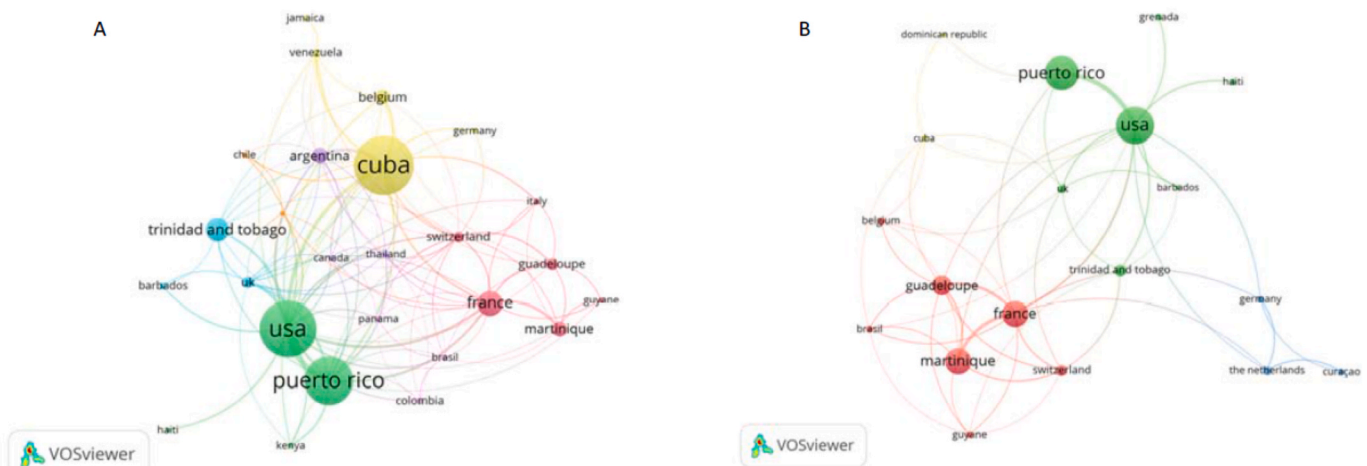
Collaboration between Caribbean countries in the field of arboviruses is not especially strong. The perspectives for these countries to exchange between themselves could be favored by several factors. For example, implementation of multinational calls for projects in the Caribbean region, on public health themes specific to these territories, and launched by these organizations, would be a real boost. Indeed, we have observed that the projects financed by regional public health institutions such as PAHO and CARPHA are weakly represented, with only 5 publications out of 536, i.e. less than 1% financed by these two main institutions in the Caribbean. Second, the more frequent organization of scientific events on the topic of arboviruses could also promote the creation of collaborative links between scientific teams, which could in turn lead to joint publications. Third, in order to promote the development of clinical research in these territories, it would be necessary to move towards the homogenization of the regulatory systems of the different Caribbean countries. Indeed, there are around twenty countries in the Caribbean, all with different status, such as independent countries, British territories, federal states of the Netherlands, territories of the United States and French Overseas Departments. As a result, there is wide heterogeneity in the regulations for clinical research, which is an obstacle to productive collaboration.



**Fig. 4.** Proportion of articles published by Caribbean countries: DENGUV vs emergent arboviruses (CHIKV and ZIKV)  
Legend of Fig. 4: Absolute numbers are available in each bar Percentages are computed by island.



**Fig. 5.** Temporal trends in the number of first and last authors in articles of dataset from 1980 to 2020  
 Legend of Fig. 5: Fig. 5 represents the evolution of the number of authors by year from 1980 to 2020, and by Caribbean island.

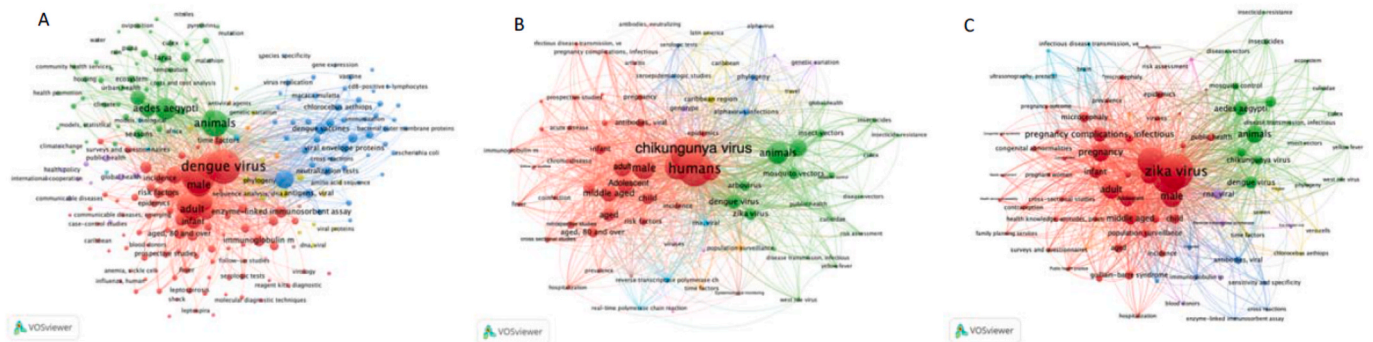


**Fig. 6.** Network visualization of collaborations between countries for publications on emergent arboviruses with DENG (A) (CHIKV + ZIKV) (B)  
 Legend of Fig. 6 and 7: VOS Viewer visualization of the most frequently related terms and extracted from Web of Science. Each term is represented by a circle, where its diameter and label size is proportional to the number of publications that have the corresponding term in their title or abstract. Colors indicate clusters of terms that have occurred more frequently in the dataset. A shorter distance between nodes and/or a thicker line connecting nodes indicates higher intensity of collaboration between authors from the respective countries. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

One of the strengths of this article is the fact that, to the best of our knowledge, it is the only bibliometric study to focus on the 3 major arboviruses in the Caribbean with significant impact on public health. Our study attempts to describe the dynamics of scientific production and collaborations at the Caribbean and international level, in the face of the new epidemic emergence of arboviruses (ZIKV and CHIKV) and DENV, observed for many years in these territories. Social network analysis enabled us to easily identify the forces at work and to describe the patterns of Caribbean collaboration between organizations and researchers. Our bibliometric study attempted to focus more specifically on Caribbean islands that are directly exposed to epidemic waves and that are poorly represented internationally.

One of the limitations of this article is the lack of exhaustiveness in

international databases of the results obtained from the research conducted. However, this can be balanced by the fact that we focused on peer-reviewed articles, which implies certain quality criteria and relevance within the scientific literature context. By focusing on Medline-indexed publications, other potential articles of interest were not analyzed. Information about the source of funding was available for only 40% of articles, and we cannot be sure of the completeness of this information, as the information was not provided in more than half of the articles. Research on the co-authorship network may be potentially biased by frequent large-scale misspellings of authors' names [39]. The citation analysis used to determine the quality of an article may be unreliable, especially for more recent publications. It should also be noted that large numbers of citations per article may be the result of both



**Fig. 7.** Network visualization of keywords related to arboviruses: DENGV (A), CHIKV (B), ZIKV (C) in Caribbean countries)

Legend of Fig. 6 and 7: VOS Viewer visualization of the most frequently related terms and extracted from Web of Science. Each term is represented by a circle, where its diameter and label size is proportional to the number of publications that have the corresponding term in their title or abstract. Colors indicate clusters of terms that have occurred more frequently in the dataset. A shorter distance between nodes and/or a thicker line connecting nodes indicates higher intensity of collaboration between authors from the respective countries. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

important and useful results, but also of criticisms related to poor methodology and questionable results. A textual analysis would have enabled a more comprehensive approach to the research themes covering all three arboviruses [40]. Finally, the choice of first and last authors in our study is probably not a universal practice in all fields of science. Nevertheless, in the medical field (which concerns the vast majority of the articles in our study), this practice is very common.

## 5. Conclusions

Over the last 40 years, the volume of publications from Caribbean islands in international journals on arboviruses has improved significantly. Collaborative efforts between all Caribbean islands must be strengthened to continue to improve the quality and quantity of articles on arboviruses. Our co-authorship network analysis on emerging arboviruses enabled us to identify the dynamics of existing partnerships, and thus to gain insights into Caribbean collaborations to be created and consolidated in case of resurgence of new arbovirus epidemics.

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## CRediT authorship contribution statement

**Cédric Contaret:** Conceptualization, Data curation, Formal analysis, Project administration, Software, Visualization, Supervision, Validation, Writing – original draft, Writing – review & editing. **Raymond Césaire:** Supervision, Validation. **Jacqueline Deloumeaux:** Writing – review & editing. **Clarisse Joachim:** Writing – review & editing. **André Cabié:** Conceptualization, Writing – review & editing. **Moustapha Dramé:** Conceptualization, Writing – review & editing, Validation.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.tmaid.2022.102396>.

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