Bibliometric Analyses on EU-Africa Research Co-publications in Climate Change

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Building Bi-regional Partnerships for Global Challenges

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2. List of Abbreviations

BRIC	Brazil Russia India China
CNRS	Centre National de la Recherche Scientifique
DAAD	Deutscher Akademischer Austauschdienst
DST	Department of Science and Technology (South Africa)
EC	European Commission
EDCTP	European & Developing Countries Clinical Trials Partnership
EU	European Union
FP6	Framework Program 6
FP7	Framework Program 7
IPCC	Intergovernmental Panel on Climate Change
NSF	National Science Foundation
RDI	Research Development Innovation
SSA	Sub-Saharan Africa
STI	Science Technology Innovation
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WoS	Web of Science
WP	Work Package

3. Executive Summary

This investigation is commissioned by the Department of Science and Technology as co-leader in work packages 4 and 5 of the CAAST-Net Plus project. The investigation aims to undertake a bibliometric analysis of co-publications between Africa and Europe in the field of "climate change" and to inform relevant policy by revealing the trends in bi-regional research collaborations and the publication of research.

It is stated that the CAAST-Net goal statement was to contribute towards *"an increase in the quality and quantity of bi-regional cooperation in science and technology between Europe and Africa, targeting areas of mutual interest and benefit through greater use of instruments under the FP7, as well as through other instruments of international cooperation, and through lobbying for greater synergy between R&D and development instruments" (CAAST-Net Plus History p2).*

Climate change is one of the top priorities in the bi-regional cooperation between Africa and the EU. The Joint Africa-EU Strategy (Africa et al 2007) identifies that the significance of climate change lies in its global interconnection and its impacts on water resources and food security. Environmental degradation and climate change undermine sustainable development and represent threats to the achievement of the Millennium Development Goals. The issue of climate change is of particular importance for the European partners too. The EU decided that at least 20% of its budget for 2014 to 2020 – as much as €180 billion − should be spent on climate change-related actions. To achieve this increase, mitigation and adaptation actions will be integrated into all major EU spending programs.

The results and recommendations of the current investigation are based on an in-depth literature review and a set of bibliometric analyses. The bibliometric analyses utilise the Web of Science (WoS) and is based on an information retrieval approach emphasising precision.

The review related to research collaboration identifies that international collaboration is an international phenomenon fuelled by a multitude of factors such as access to facilities and funds and a number of authors suggest that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries.

Collaborative research as it is manifested in co-authored articles including African researchers has increased substantially since 2003, taking place in particular disciplines neglecting scientific and technological disciplines underpinning modern economies (e.g. engineering) and emphasised in other countries (e.g. China).

The literature also identifies that there is limited collaboration among themselves of African researchers and that individual African countries exhibit substantially higher collaboration patterns than the rest of the World.

Apart of the international forces such as globalization leading to collaborative research, availability of resources appears to lead collaboration in Africa. Local historical and cultural characteristics are further superimposed on the phenomenon.

The literature related to climate change identifies that there is a weak link between research and implementation and efforts to influence policy making; that potential African partners in bi-regional consortia are financially constrained and in need of seed funding to enable them to take part from the start of project design to submission of proposals. The lack of seed funding may contribute to

the finding that specific local factors are not considered or sufficiently accounted for in the generation and implementation of climate change knowledge.

The bibliometric analyses reveal the following:

- Climate change research in Africa and in collaboration with Europe increased substantially during the period 1993-2015, albeit from a very small base. The estimated increases were substantially higher that the growth of the African articles (articles with African researchers from all disciplines) during the period. Estimation of the ratio of climate change research to total research shows that Africa' ratio is three times as high as those of China, India and Brazil-indicating a sensitivity of Continental priorities to international collaboration. During 2015, the activity index of climate change research in Africa was 1.5. This means that Africa was undertaking 1.5 times more research related to climate change than what is expected by the Continent's total research outputs. The EU activity index was 1.3.
- Forty six percent of the climate change research in Africa is produced in collaboration with Europe and the Africa-EU collaboration (all disciplines) contributes 30% of the total research output of the African Continent. The analysis provides support to the evidence from the literature that international research support is critical for Africa.
- African researchers collaborating with Europeans publish also articles without their European partners (spill-over effect).
- The FP6 and FP7 had a substantial impact on the number of co-authored climate change articles. The estimated impact is substantially bigger than the growth of African climate change articles (without European participation) and the growth of all African articles (all disciplines) (Table 2).
- Climate change articles with EU collaboration perform almost twice better in terms of citations per article and citations without self-citations than the set without EU collaborators. Similarly, the H-Index of the collaborative set is higher than the index without the EU collaborators.
- Identification of the funders (as they acknowledged by the authors) in the set of articles co-authored among African and EU authors shows that the European Union in its various permutations was the most often mentioned funder. It was mentioned in 158 articles. The National Research Foundation (of South Africa) was the second most often mentioned funder (73 times). The European Union was mentioned twice as often as the NRF which is probably the most important research funder in the Continent. Other funders mentioned are the National Science Foundation (USA); the Leverhulme Trust; Wellcome Trust and others.

The report makes the following recommendations:

- CAAST-Net and CAAST-Net Plus supported by the Framework Programmes appear to have been successful in encouraging more and better bi-regional STI cooperation for enhanced outcomes related to climate change. The success is particular important as Africa had limited, if any expertise, in the field in the 1990s. It is suggested that similar approaches can be utilised to develop research capacity and cooperation in other fields of common interest and priority.
- The collaborative patterns in a variety of African countries reveal dependency of the local research systems on international resources. Furthermore, the high degree of current collaboration indicates that there might be limited scope for additional expansion. African governments, multilateral organisations and their international partners should focus in developing research capacity. Providing funding rewards for research publications has been proven effective in South Africa and can be used across the Continent.

- The small scientific size of Africa and of African countries makes the issue of research priories of critical importance. Prioritization is required across the broad main domains and within each domain. The field of foresight has been identified to be useful in that domain. National and regional exercises can introduce the concept to the relevant authorities. Such exercises could also guide the European Commission in enhancing its collaborative efforts with Africa.
- The small size of research systems, lack of funds for co-financing and dependence on international resources are manifestations of the refusal or neglect of African governments to accept that innovation is the fundamental cornerstone of economic growth, employment, international competitiveness and development. African governments, multilateral organisations and their international partners should aim to institutionalize the governance and support of science, technology and innovation.

4. Background and Context

The *Network for the Coordination and Advancement of Sub-Saharan Africa-EU Science and Technology Cooperation* (CAAST-Net) was a project funded by the European Commission. The establishment of the Network followed the development of the Joint Africa-EU Strategy during 2007. The purpose of the Joint Strategy is to take the Africa-EU partnership to a new strategic level with a strengthened political dialogue and enhanced cooperation at all levels.

Under the Joint Africa-EU Strategy eight so-called partnerships made up the priority areas. These were[1]:

1. Peace and security;
2. Democratic governance and human rights;
3. Regional economic integration, trade and infrastructure;
4. Millennium Development Goals;
5. Climate change;
6. Energy;
7. Migration, mobility and employment;
8. Science, information society and space

Partnership 8 as it came to be known carried a specific mandate to advance bi-regional collaboration in the domains of science, information society, and space.

CAAST-Net was conceived against the background of a global consensus that capacity in science and technology is essential to economic competitiveness, sustainable development and poverty reduction. This new geo-political relationship reflects the global trend towards seeing scientific and technological RDI as a driver of economic growth, a move away from a 20th century focus on capital, natural resources and labour (EC 2002). The CAAST-Net goal statement was as follows:

"An increase in the quality and quantity of bi-regional cooperation in science and technology between Europe and Africa, targeting areas of mutual interest and benefit through greater use of instruments under the FP7, as well as through other instruments of international cooperation, and through lobbying for greater synergy between R&D and development instruments" (CAAST-Net Plus History p2).

[1] EU (2014) "The Africa-EU Partnership: 2 Unions, 1 Vision" at http://www.africa-eu-partnership.org/sites/default/files/documents/jaes_summit_edition2014_en_electronic_final.pdf

A challenge for P8 has been establishing the modalities for translating the proposed P8 activities into concrete projects which can accomplish the articulated objectives. This challenge was tackled in 2008 through the design of 19 large outline projects which constituted the so-called Book of Lighthouse Projects (such as the Africa Research Grants Programme, the African Virtual Campus, African Leadership in ICT, and Global Monitoring for Environment and Security for Africa.
The CAAST-Net operated during the period 2008-2012 and it was followed by CAAST-Net Plus. CAAST-Net Plus is a network of 26 partner organizations from Europe and sub-Saharan Africa working together to support bi-regional cooperation in research and innovation. The CAAST-Net Plus aims to:

- "Encourage more and better bi-regional STI cooperation for enhanced outcomes around topics of mutual interest, and particularly in relation to the global societal challenges of climate change, food security and health.
- Foster discussion among stakeholders for gathering informed opinion and experience about the bi-regional cooperation process, formulating and disseminating it in such a way as to be admissible to the formal bi-regional STI policy dialogue process and to programme owners." (p1)[2]

DST is a co-leader in work packages 4 and 5. The objectives of WP 4 are as follows:

- To provide a knowledge base to enrich formal and informal policy dialogue processes, including analytical evidence drawn from monitoring and analysing the progress and results of bi-regional science, technology and innovation (STI) cooperation;
- To develop and implement concepts for bi-regional STI policy stakeholder forums;
- To support and monitor the implementation of policy dialogue recommendations at the request of the Bureau of the Africa-EU STI policy dialogue platform;
- To consult a wide base of stakeholders to gather and consolidate evidence to inform international cooperation policies and/or instruments.

In the above context DST has commissioned the current bibliometric analysis which aims at monitoring research co-publications between Africa and the EU. "The bibliometric studies on co-publications will provide analyses that aim to inform policy by revealing the trends in bi-regional research collaborations and the publication of research thereof".

More specifically the terms of reference state that the studies will:

- Analyse national, regional and global discourse and policy imperatives on climate change, health and to an extent food security and topics related to these societal grand challenges which are of both national, regional and global interest;
- Provide an analysis on the impact of co-publications within the bi-regional research and innovation landscape;
- Uncover and provide a critical analysis of the factors which have driven collaborative research between African researchers and their European counterparts;
- Highlight the financing trends of health and climate change research (as they are revealed by the authors of research);
- Compare research co-publications outputs between EU-Africa;
- Review literature related to EU-Africa research and innovation collaboration landscape;
- Identify the trends in health research and climate research co-publications between EU and Africa from 1993-2015;

[2] CAAST Net plus "Science, Technology and Innovation Cooperation between Sub-Saharan Africa and Europe" accessed at https://caast-net-plus.org/about/goals

- Compare trends in FP6 and FP7 funded research and innovation co-publications, as well as preceding R&I funding instruments;
- Analyse the rate in co-publications between the years 1993 and 2015 and
- Provide policy recommendations that will influence the numbers and activity of research co-publications.

5. Methodology

The results and recommendations of the current investigation are based on an in depth literature review and a set of bibliometric analyses. The literature review is distinguished into literature related to research collaboration: definition and types; collaboration motives, objectives and impacts; collaborative research, development and innovation (RDI) patterns in Africa; and climate change.

Bibliometric analyses require the identification of a relevant database and a methodological approach for identifying the under examination (target) documents.

There are a number of specialized databases (e.g. Chemical Abstracts covering physics and chemistry; Compendex covering engineering and technology; Embase covering medical sciences, and so forth). However, these databases cannot be used for scientometrics purposes as their coverage is not homogeneous – they include different types of data or no data at all for particular topics and they usually contain monographs, theses; books and articles – and/or they incorporate in the databases documents which are not examined for quality. Furthermore, not all databases include all authors' addresses, documents from other countries (for comparative purposes) and so on and hence, the identification of all contributors to the research is not possible. Similarly, citation incorporation is necessary for the identification of the impact of the different sets of publications.

The most frequently used databases for bibliometrics are the WoS and Scopus. The two databases compete with each other and internationally published comparisons find small differences. For this investigation we propose to use the Thomson-Reuters (WoS) databases as they cover all the important journals in the world and data are available for the period under investigation.

Bibliometric analyses related to "climate change" have been challenged by the concepts of recall and precision. The issue refers to the credibility of extracted data when key words are used. The issue is of particular importance for "climate change" analysis. The two relevant questions are: do we retrieve *all* the target population documents? And are all the documents *relevant* to the topic under investigation?

In information retrieval, a perfect precision score means that every result retrieved by a search was relevant (but says nothing about whether all relevant documents were retrieved) whereas a perfect recall score means that all relevant documents were retrieved by the search (but says nothing about how many irrelevant documents were also retrieved).

To give an example: in order to retrieve as many documents as possible in the topic of "climate change" we can search for these terms in the title, abstract and key words of documents (an approach which is followed by a number of authors). However, such a search will also retrieve a large number of documents that are not relevant to the topic with adverse consequences for any subsequent analysis and conclusions. One of the important reasons is the fact that the search does not retrieve only the words climate change when they are the one next to the other but it retrieves all documents which they have the words climate and change in the title, abstract and key words independently of how far apart are the two words.

For this investigation particular emphasis is placed in precision and the relevant articles were identified following three different approaches: in the first set all articles in journals including in the journal's title the term "climate change" were included. We suggest that the editors and the editorial boards of these journals will not accept articles that are not related to climate change. The second set includes all articles that in their titles include key words having been identified as synonyms of climate change (Haunschild et al 2016). The strategy is as follows: (Climat* and (chang* or warming or temperature* or model* or system* or mitigation* or adaptation* or effect* or polic*) or greenhouse and (effect* or gas*or warming*) or global* and (warming* or temperature* or environmental change) or ocean acidification or Kyoto protocol). Asterisks were used in order to cover truncation (e.g. climat* covers climate, climatic, climates etc). The existence of these terms in the titles of articles indicates that the articles are investigating issues of climate change. The above two sets are high in precision but they may have omitted articles that were published in journals that they don't have the words climate change in their tiles and articles that they don't have the relevant key words in their titles. The third set includes articles which in their title, abstract or key words include in close proximity the words climat* chang*. The Boolean operator "near" was utilised. The operator near improves precision by eliminating articles in which the two terms are far apart.

Collaborative articles were identified from the authors' addresses. Data are identified per annum for the period 1993-2015 and hence, time trends can be discerned. Two different sets of articles are identified – collaborative articles between Africa-Europe in climate change – and Africa only articles (without European collaborators). Comparisons of the two sets can provide evidence of the European influence on Africa's related research. Further comparisons with the broad growth of research articles in Africa can reveal the impact of the collaboration.

Trend analysis of the collaborative efforts during the Sixth Framework Programme (FP6) for Research and Technological Development (2002-2006), the Seventh Framework Programme (FP7) for Research and Technological Development (2007-2013) and most recently, the Horizon 2020 Framework Programme for Research and Innovation (2014-2020) can provide indication of impact, changes in emphasis/support and similar.

As Thomson Reuters indexes the funders of research as they appear in the various publications, bibliometric analysis can identify the frequency of appearance of the various funders of collaborative bi-regional research.

For the assessment of the citation impact of the collaborative articles we will develop two sets of articles – climate change articles in collaboration with European researchers – and African articles in the field without European collaboration. For the two sets we estimate their H-Index and make comparisons. The h-index for an author, country or set of articles is the number h of papers among an author's or a country's/set's number of publications that have at least h citations each (Hirsch 2005). Similarly the average number of citations received per article and citations without self-citations per article will be estimated for the two sets of articles. As both sets have been identified through the same process (subject discipline and publishing period) and differ only in the co-authors the comparison will be valid and revealing.

The convergence of the finding in the literature review and the bibliometric analyses lead to the development of a set of recommendations.

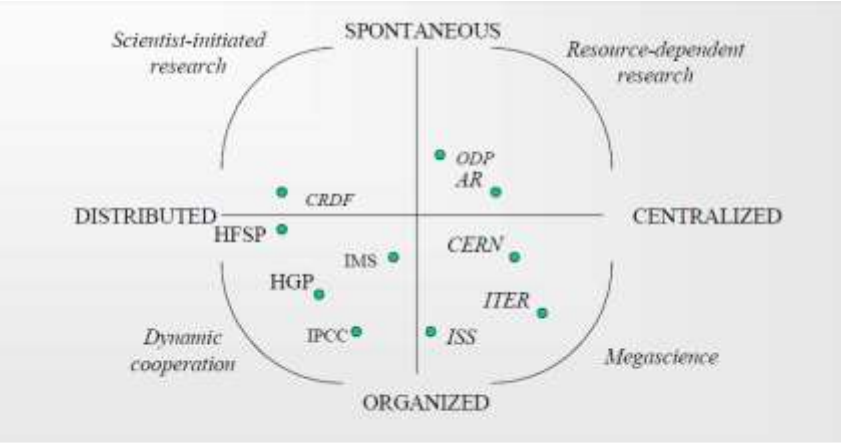
6. Research Collaboration

6.1 Definition and Types

There are limited efforts internationally to answer the question what constitute research collaboration even though common sense defines collaboration as the 'working together of individuals to achieve a common goal of producing new scientific knowledge'. This however, raises the question of how closely researchers have to work together in order to constitute a collaboration. On the one extreme it can be argued that anyone providing an input to a particular piece of research should be considered a collaborator. On the other extreme, it can be argued that only those who contributed directly to all the main research tasks over the duration of a project should be termed as collaborators/co-investigators.

The precise nature and magnitude of any collaboration cannot be easily determined by the usual methods of observation, interviews or questionnaires due to the complex nature of human interactions. For example, Katz et al (1997) argued that the line separating informal links between scientists and more formal collaboration is also blurry. Moreover, both the nature and magnitude of the contribution of the various participants are likely to change during the course of a research project.

Katz et al, (1997) elaborating on the issue concluded that research collaboration has a very fuzzy or ill-defined border. There are different types of collaboration, which in turn create different management requirements. Figure 1 presents the different types of collaboration. The Figure shows two axes that can describe different organisational forms of collaboration. One axis runs from spontaneous ("bottom-up") research deriving from the interests of scientists, to highly organised research defined by a funding party. The other axis defines degree of centralization of the effort. These two axes form four quadrants which characterize collaborative research. Activities on the left-hand side of the diagram might be described as "dynamic", in that the collaboration requires active learning and sharing of tasks and information among researchers who are often geographically dispersed. Activities on the right-hand side might be described as material/institutional research in that collaboration relies on a shared resource or common research location. Mega-science projects could be placed in the bottom right quadrant, organised and centralised. Scientist-initiated research would be placed in the upper left quadrant.



*Key: **HFSP**=Human Frontiers Science Program; **HGP**=Human Genome Project; **AR**=Arctic Research; **IMS**=Intelligent Manufacturing Systems; **IPCC**=Intergovernmental Panel on Climate Change; **CERN**=European Organisation for Nuclear Research; **ITER** (fusion research); **ISS**=International Space Station; **ODP**=Ocean Drilling Program; **CRDF**=Cooperative Research and Development Fund.*

Figure 1: Types of Collaboration. Source: RAND 2002

Similarly, multinational collaborations are characterised according to the participants. There are:

- National programmes open to foreign participation
- Bilateral programmes
- Multilateral programmes
- Regional programmes (e.g. EU Framework programmes)
- Bi-regional programmes (e.g. EU-Africa programme)

Programmes do not need to be static. For example, they can start as bilateral activities and subsequently become multilateral by allowing additional partners. Furthermore, the programmes may vary in terms of scope. For example, they can vary with regard to scientific or technological domain they cover or according to a spectrum from basic research to technology transfer and near market deployment.

The disciplinary character of collaboration presents another interesting dimension. Empirical studies show an increase in research joining together several disciplines (Wagner et al 2011) and a number of policy authorities including at the EU, have increasingly supported this mode of research (Van Rijnsoever et al 2011).

Publications with multiple authors are considered the natural output of any research collaboration. De Solla Price (1963) was among the early proponents of using multiple-author papers as a measure of changes in collaboration.

Currently there is a general consensus that co-authorship is reflective of collaboration and organisations like the National Science Foundation (NSF) in the USA and the European Commission in Europe publish regularly relevant statistics and analyses.

Although the assessment of collaboration using co-authorship is by no means perfect, it nevertheless has certain advantages. Firstly, it is invariant and verifiable. Secondly, it is a practical method for quantifying collaboration. Thirdly, the approach is viable for large samples (in contrast to case studies), and finally, the approach is unobtrusive and non-reactive (does not affect the collaboration process).

6.2 Motives, objectives and impacts

Research collaboration is a sociological phenomenon receiving attention by researchers and governments internationally (Yeung *et al*., 2005). Researchers investigate the effects, modes, dynamics and motives of collaborations, while governments utilise research collaboration as a policy instrument for technology transfer from universities and research councils to industry (intra-collaboration); for knowledge transfer from abroad (inter-collaboration); as means to improve diplomatic relations with other countries by creating good will; and gain political capital (RAND 2002), and others.

Researchers collaborate with each other for various reasons. They do so in order to improve their visibility and recognition (Narin *et al.,* 1991), in order to utilise expensive equipment and facilities which are not under their control (Meadows *et al.,* 1971; Schubert *et al.*, 2010); to acquire expertise and new ideas (de B Beaver *et al*, 1978) needed for their research and others. Among the other reasons are included historical ties; linguistic preferences; geographical proximity; and specific problem issues (e.g. disease control or natural disaster mitigation) (Adams et al 2013). The substantial fall in the costs of air travel and communication, advances in effective information and communication methodologies further accelerated collaborative activities during the recent

decades. Finally, Wagner & Leydesdorff (2005) argued that patterns in international collaboration in science can be considered as network effects and that only the European FPs noted by Georghiou (1998) mediated relationships at that level.

In the policy domain scientific collaboration has become an important component of science, technology and innovation policy internationally with substantial resources allocated by governments for this objective. Government involvement in collaboration programmes is based on the recognition that research does not stand alone. It is one aspect of an intensively competitive ecosystem of knowledge development and commerce. Recognition of this context sets the basis for multinational collaborations. Governments are becoming active supporters of research collaboration and institutionalize such efforts. Examples include Australia (Australian Government, 2011); Canada (NSERC, 2013) and others.

National strategies for participation in that ecosystem can have one or more of several bases. For example, they may be based on the desire to develop the country's S&T competence with a view to its future exploitation. A government strategy might have the aim to open their researchers to external ideas and then to induce them to compete with their peers internationally. Another might be based on developing the attractiveness of the country for inward investment – not just on R&D. (CISTRANA 2006).

It should be emphasised that every country will have different motivations for collaboration in different sectors and technical fields based on the perceived potentials and anticipated developments in science and technology.

Russell, (1995) and Wagner et al (2001) suggested that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries. However, they qualified their findings by stating "Nevertheless, S&T capacity building does not automatically result from these activities" (Wagner, *et al.,* 2001 p XV). More specifically the authors suggest that "if the country lacks the ability to absorb that knowledge and put it to good use, its potential positive and lasting effects will simply drain away... In the case of scientific research, this requirement constitutes a baseline level of scientific infrastructure to make collaboration an effective mode of capacity building. Nations, having capacity below this baseline level, cannot measurably use collaboration to build capacity. Above the baseline, collaboration becomes a viable mechanism (if not completely sufficient) for augmenting capacity... The required baseline level of capacity is not fixed and likely differs among countries; field of studies and even among specific research problems within fields" (p62).

A number of authors (Narin et al 1991), hypothesised that smaller countries may have smaller single country publications due to the scarcity of collaboration opportunities at the national level. The argument appeared to be that the collaborative effort is initiated by researchers in small countries who cannot find collaborators. However, Melin (1999) concluded that ''the results indicate that the situation is much more complex than that large country researchers collaborate less internationally than small countries as their scientists more easily can find their partners within the national borders than in smaller countries.'' Georgiou (1998) suggested that researchers in less developed countries can participate in collaboration only when a formal framework and budget is in existence. Similarly, Boshoff (2009) identified that north–south collaboration takes place in a particular format with the south collaborator basically assisting in field wok and data collection. In other words the developed countries' researchers seek collaboration in order to access data and conditions available in the developing countries.

From a theoretical, utilitarian perspective, international collaboration is not without its challenges. S&T policy aims to maximize the benefits of a particular group/institution or nation. However, 'advantageous' collaboration may not be easily achievable (or feasible) among different partners and similarly, approaches that maximize national benefits may not achieve the same effects at a multi-country or regional context. A second issue that is apparent in the policy context is that collaboration is an instrument of S&T policy aiming at achieving a variety of different policy (targets).

The most often mentioned objectives are: to get access to knowledge unavailable locally; to share costs and risks; to get access to partners' markets; to achieve standardization and to fulfil political considerations. Gaining access to knowledge and sharing costs and risks are objectives internal to S&T policy, while the other objectives should be seen as external to science and technology but achieving objectives in other spheres of governance. Obviously there is no reason why collaboration cannot be formulated in such a way as to achieve more than one objective (e.g. one internal to S&T and one external) but building such instruments may be challenging. Other concerns expressed include the argument that the spending in international collaboration is not always to the benefit of the paying country and that critical technologies and key knowledge for competitiveness are given away to competitors. Additional concerns have been voiced that collaborative agreements may subordinate the interests of science and technology to strategic or political ends. Similarly in the academic domain, researchers have argued that collaboration may be an endogenous self-perpetuating outcome of science with substantial costs and no commensurate benefits (Jones, *et al*., 2008).

An additional line of research argues that international collaboration is a self-organising system with its own dynamics. Leydesdorff, *et al.,* (2008) suggest that international collaboration can be considered as a communications network that is different from national systems and has its own internal dynamics and exists primarily as a self-organising system.

The authors argue that the new order of things means that nations must take careful stock of the conduct of science at the global level as well as at the national and regional levels. As the system expands, useful innovation can increasingly occur somewhere else; identifying innovations and making them locally available will be a major challenge for policy makers. Finding ways to evaluate distributed scientific research and local absorptive capacity is another.

"Furthermore, they suggest that it may become increasingly difficult to track spending and attach it to outputs and outcomes, which has been the model for much of public accountability for science in the past" and that "managing a complex, open system requires crafting new incentives to encourage knowledge flows and participation that favours the peripheral members."

Empirical evidence shows that research is increasingly collaborative (Gibbons et al 1994, Van Rijnsoever et al 2011). The EC (2015) states: "Whereas fewer than 5% of the papers in 1980 comprised authors' addresses from at least two countries, this figure is now closer to 25%, a remarkable fivefold growth in 35 years"(p8). However, despite this body of evidence there is no any theoretical satisfying explanation for the phenomenon. Wagner (2005) suggested that "the theoretically satisfying explanation may be elusive in part because we have an incomplete understanding of the dynamics of collaboration at the global level and how it differs from nationally or institutionally based research or localized collaboration"(p1).

The literature on the effects of collaboration focuses on issues of productivity and impact. The findings related to productivity are that scientific output, as measured by publications in the open literature, is closely dependent on the frequency of collaboration among authors (Radhamany, 2014, Eslami, *et al.,* 2013, Abramo, G et al*,* 2009).

As far as impact is concerned, Narin, *et al*. (1991) and Gomez, *et al*. (1995) identified that internationally co-authored papers tend to have on average higher citation rates. However, Moed (2005) identified that citation depends on who is collaborating with whom. He suggests that when scientifically advanced countries collaborate with each other the citation impact of those papers is higher than it is the case for the purely domestic papers. When scientifically advanced countries collaborate with scientifically less advanced countries, the outcome may affect negatively the citation rates of the advanced country.

6.3 Research, Development & Innovation patterns in Africa

Relatively few investigations examine the collaborative patterns of research in the African Continent. A recent World Bank report provides general background information about research and collaboration in Africa. The World Bank report (World Bank and Elsevier 2013) examines the research enterprise over a decade from 2003 to 2012 of three different geographies in sub-Saharan Africa (SSA): West & Central Africa (WC), East Africa (EA), and Southern Africa (SA). Some of the findings are as follows:

1. Sub-Saharan Africa has greatly increased both the quantity and quality of its research output.
2. SSA research output in Science, Technology, Engineering and Mathematics lags that of other subject areas significantly.
3. SSA, especially East Africa and Southern Africa, relies heavily on international collaboration and visiting faculty for their research output.
4. Research collaboration in Africa features a number of particular characteristics that are critical to understand for the design of successful policies. Some of the characteristics are as follows: SSA's research capacity appears fragmented across regions with each region collaborating very little with one another. There appears to be little knowledge transfer and collaboration between African academics and the corporate sector.

The authors make a number of statements that we quote here:

"The impressive improvement in SSA's research capacity in the Health Sciences demonstrates that persistent support and funding from development partners and governments pays off. There is clearly a large scientific talent base in Africa, but this needs to be trained and nurtured" (p3).
"A very large share of SSA research is the result of international collaboration" (p4). The World Bank notes that the high reliance on international collaboration for research signals a lack of internal research capacity and the critical mass to produce international quality research on its own.
These results echo to a certain extent previous investigations (Thomson Reuters 2010; Boshoff 2009; Radhamany 2009). Similarly, Onyancha et al (2011) identified that collaborative production of knowledge among sub-Saharan African countries is minimal.

An EC (2014) investigation focused in mapping best practice in STI initiatives between Africa and Europe. The investigation aimed to assess existing bi-regional STI cooperation initiatives and to identify successful, best practice models of cooperation between Africa and Europe, as well as to identify gaps and effective financial mechanisms that have a positive impact.

The report identifies features and components of collaboration viewed as good practice and which appear to be key to effective collaboration. The report states "Partnerships and personal relations are supremely important, and effective partnerships are seen as a key criterion for effective collaboration. Joint funding, strong leadership and effective governance; clarity and understanding

of joint objectives; strong interpersonal relations; equitable resource and benefits sharing; and full transparency and communication all build mutual trust and foster co-ownership, which are necessary conditions for optimal efficiency" (p8).

The authors identify that co-ownership is a core value of bi-regional cooperation. They further state: "The single most important factor in fostering co-ownership is co-financing, whether through joint financing with existing instruments or through the creation of new, dedicated co-funded instruments" (p7). The European & Developing Countries Clinical Trials Partnership (EDCTP) and the Product Development Partnership Programme are mentioned as examples of a good practice co-financing model.

The authors suggest that the design, piloting and scale-up of co-financing arrangements using existing instruments and the joint financing of new instruments are among the highest priorities for collaboration.

A recent article (Pouris et al 2014) investigated the research emphasis and collaboration in Africa during the 2007-11 period. The authors' findings indicate that the continent's research emphasises medical and natural resources disciplines to the detriment of disciplines supporting knowledge based economies and societies. Furthermore, they identify that the collaborative patterns in Africa are substantial higher than in the rest of the world.

More specifically the authors identified that hat the most emphasised research fields are those of tropical medicine (12.5 times bigger than that expected from the scientific size of Africa), parasitology (6.5 times bigger) and infectious diseases (4.6 times bigger). The list of emphasised research areas are dominated by medical and natural resources fields (biodiversity, water resources, entomology, mining, etc.). Disciplines underpinning modern technologies and economies (i.e. engineering, physics, material sciences, instrumentation and similar were identified to be underemphasised. The authors compare African priorities with those of China and ask rhetorically why Africa does not follow international examples.

The authors compare the share of internationally collaborative articles for Africa (**54%**) with those of a number of other countries. The BRIC members, which include Brazil (**26%**), Russia (**33%**), India (**20%**), and China (**23%**), had relatively similar percentages of internationally collaborative articles. Higher percentages could be found in the G7 countries, including the USA (**33%**), Germany (**51%**), Japan (**26%**), the UK (**54%**), France (**52%**), Italy (**44%**), and Canada (**49%**). The authors state: "the individual African countries exhibit substantially higher collaboration patterns. Nigeria was the only country with a collaboration rate lower than **50%**. Twenty-nine countries published more than **90%** of their articles in collaboration with other countries. It is possible that the division of the continent into 54 countries may be a contributor to the substantial number of collaborative articles but other factors may also affect the apparent pattern" (p2177). A sample update for 2014-15 indicated the same pattern. Examples include Zambia **6%** without international collaborators; Gambia **2.6%**; Mozambique **5.4%**; Angola **9.8%**; Burundi **7.3%.**

The authors note that the number of collaborative articles with authors outside Africa is many times bigger than the African collaborative articles. The authors ask: "What drives researchers, say in Botswana and Zimbabwe, to produce more than74 % of their collaborative publications outside Africa? South African universities are a few hours away by car. Europe and the USA are a number of hours away by plane. Similarly, why does Egypt collaborate almost exclusively with non-African countries?" (p2184). They suggest that African collaboration is not driven by local researchers searching for collaborators, but by the availability of resources and interests outside the Continent.

The authors conclude: The revealed structure raises a number of policy concerns. Should Africa's science and development not be better served by the creation of regional research and innovation systems (that is aiming to create an African Research Union)? How do the high dependencies on non-African collaboration affect the continent's research evolution and priorities? Is African research individualism and inspiration stifled by excessive collaboration?"

Confraria et al (2015) estimated that the number of African publications increased from a share of 1.4% in the 1990s to 2.6% of the World literature during the 2010s. Furthermore, they have summarised the forces enabling collaboration. They suggest that Algeria and Tunisia have unique links with France and that the share of international co-authorship with France is 42 and 33 % respectively. The same happens with the UK's former colonies. Malawi and Kenya have collaboration shares with the UK of 45 and 24 %, respectively. Similarly they quote Adams et al (2010) who speculates that the USA is a main collaborating country mainly because of the researchers who have studied in the USA. Other examples mentioned refer to Gambia as the site for long-term research into tropical diseases for the UK's Medical Research Council; The Wellcome Foundation with similar, major research investments in Kenya and Malawi and similar.

To summarize, the literature review identifies the following:

- Research collaboration does not have an exact definition. It has a very fuzzy or ill-defined border.
- International collaboration is an international phenomenon fuelled by a multitude of factors such as access to facilities and funds; historical ties; linguistic preferences; geographical proximity; easiness of communications and others.
- A number of authors suggest that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries. However, there are a number of caveats linked to the above statement. The existence of a critical research basis appears to be a prerequisite.
- Collaborative research as it is manifested in co-authored articles including African researchers has increased substantially since 2003.
- African collaboration takes place in particular disciplines neglecting scientific and technological disciplines underpinning modern economies and emphasised in other countries (e.g. China).
- There is limited collaboration among themselves of African researchers.
- Individual African countries exhibit substantially higher collaboration patterns than the rest of the World. Twenty-nine African countries published more than 90 % of their research articles in collaboration with other countries.
- Apart of the international forces leading to collaborative research, availability of resources appears to lead collaboration in Africa. Local historical and cultural characteristics are further superimposed on the phenomenon.

6.4 Climate Change

Climate change started receiving international attention in the early 1990s. On December 1990, the UN General Assembly establishes the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change. The United Nations Framework Convention on Climate Change was adopted in 1992. UNFCCC Opened for Signature at Rio Earth Summit during 1992. During 1994 the UNFCCC entered into force with a membership of 196 parties.

During the period the Intergovernmental Panel on Climate Change (IPCC) was established. IPCC is dedicated to the task of providing the world with an objective, scientific view of climate change and its political and economic impacts. The IPCC evolved from the Advisory Group on Greenhouse Gases which was established in 1985 by the International Council of Scientific Unions, the UN Environment Program and the World Meteorological Organization.

The IPCC published its first assessment report in 1990, a supplementary report in 1992, a second assessment report in 1995, a third assessment report in 2001, a fourth assessment report in 2007 and a fifth assessment report in 2014. A sixth report is expected in 2022.

Similarly the European Commission has taken many climate-related initiatives since 1991, when it issued the first Community strategy to limit carbon dioxide emissions and improve energy efficiency. Climate change is one of the top priorities in the bi-regional cooperation between Africa and EU. The issue is elaborated in the Joint Africa-EU Strategy (Africa et al 2007). The significance of climate change lies in its global interconnection and its impacts on water resources and food security.

Environmental degradation and climate change undermine sustainable development and represent threats to the achievement of the Millennium Development Goals. Similarly, UNESCO (2013) states that environmental challenges – if inadequately understood and inappropriately managed – can impede achievement of the internationally agreed development goals, through their negative impacts on poverty eradication and social inclusion as well as on realisation of human rights for all. Two recent reports (CAAST-Net Plus 2016; CAAST-Net Plus 2014) investigated issues of scope, coordination and uptake of findings of the program and they developed relevant recommendations. The 2014 report focuses on bi-regional research funded through the European Union's Sixth and Seventh Framework Programmes.

The report considers the extent to which research knowledge is being used to inform policymakers in developing effective responses to climate change. The investigation shows that there is a weak link between research and implementation and efforts to influence policy making. The authors develop a number of recommendations: incorporate outcome thinking in the project design; promote collaboration of researchers with civil society and lobbying organisations; stimulate debate related to understanding longer term outcomes of EU-Africa collaboration and develop financing models based on more balanced partnership and cooperation.

The report "Designing and Africa-EU Research and Innovation Collaboration Platform on Climate Change" elaborates on the results of the Bergen workshop. The Bergen workshop aimed to design an Africa-EU research and innovation cooperation platform focused on climate change.
Figure 2 shows the findings and recommendations of the workshop.

We turn then to bibliometric publications investigating climate change in general. A number of bibliometrics analyses have been published stimulated by the growing scientific, political, and public attention of research on climate change. Recent examples include: Li et al (2015) used bibliometrics to study the literature in terms of trends of growth, subject categories and journals, international collaboration, geographic distribution of publications, and scientific research issues. Haunschild et al (2016) reviewed the literature during the period 1980—2014 investigating the growth of the field; the contribution of Journals and countries; their citation impact and the evolution of a number of sub-topics. Ji et al (2014) analysed research on Antarctica; Vasileiadou et al (2011) explored the impact of the IPCC Assessment Reports on science and others.

Pasgaard et al (2013) investigated whether the need for knowledge on climate changes in the most vulnerable regions of the world is met by the supply of knowledge measured by scientific research

publications from 2000-2010. The authors examined the distribution of climate change research and the potential causes of this distribution. They used 13 explanatory variables representing vulnerability, geographical, demographical, economical and institutional indicators. The investigation shows that "the supply of climate change knowledge is biased toward richer countries, which are more stable and less corrupt, have higher school enrolments and expenditures on research and development, emit more carbon and are less vulnerable to climate change". Similarly, the production of knowledge is skewed *away* from the poorer, fragile and more vulnerable regions of the world.

Table 1: Findings and Recommendations – Bergen Workshop

FINDINGS	RECOMMENDATIONS
Research on climate change is still in its infancy in Africa and Europe alike, but especially in Africa, let alone bi-regional projects on that theme.	Establish support schemes for African researchers at PhD and post-doctoral levels with bilateral donor funding, complementary to the facilities of Horizon 2020.
As a cross-cutting concern climate change is often neglected in the design of sector-specific projects.	Make it a requirement to include climate change dimensions in all project proposals to Horizon 2020, regardless of sector-specific emphasis.
The uptake of research findings by policymakers and practitioners remains a major impediment to research impact.	Establish fora or meeting places for scientists, policymakers and practitioners to interact and learn to understand each other's perspectives.
The interaction between the private sector, academia and governments is sporadic and grossly inadequate.	Develop further the embryonic collaborative venture between the East Africa Business Council (EABC) and the Inter-University Council of East Africa (IUCEA) as a partnership model to be emulated by other regional economic communities in Africa. To be successful, the inclusion of government representatives would be mandatory to form a tripartite relationship.
Potential African partners in bi-regional consortia are financially constrained and in need of seed funding to enable them to take part from the very start of project design to submission of proposals.	Develop schemes and mechanisms for accessing seed funding for potential consortia partners who are financially constrained with a view to overcoming non-academic hurdles of asymmetry between Africa and Europe.
The relationship between African and European collaborators remains asymmetrical.	Explore and further develop financing and cooperation models, such as ERAfrica, which allows for a more balanced partnership and cooperation.

Source: CAAST-Net Plus (2016)

A qualitative assessment of all titles and abstracts and a logistic regression revealed that the probability of a study investigating any social or human impacts of climate change is significantly higher in Africa and lower in North America compared to Europe. The authors emphasise that proportionally more research on climate change pertains to the developed and less vulnerable regions of the world. And that this trend both raises concerns and poses several challenges. It indicates a North–South divide between exposure to risk, vulnerability and available knowledge. The results confirm that published research on countries which are assessed at high climatic vulnerability

is lower than countries with less vulnerability. They argue that specific local factors are not considered or sufficiently accounted for in the generation and implementation of climate change knowledge and suggest that this pattern might affect the use and integration of locally generated knowledge to provide contextually relevant advice.

7. Bibliometric Analyses

As a first step and in order to set the scene, we identified all articles dealing with climate change from the period 1993 – 2015. Figure 2 shows the time evolution of the publication output in the field as they are indexed in the WoS database. The figure indicates a strong growth of the relevant articles during the period. During the period 1993 to 2015, the number of climate change papers published per year increased by a factor of seven whereas in the same time period the overall number of papers covered by the WoS databases increased "only" by a factor of approximately two (Bornmann et al 2015).

In the beginning of the period 1993-1996 the trend was flat. After that there was a small increase in the number of articles up to 2001. From 2001 to 2007 there was a doubling of the number of relevant articles (to 7242 articles). The number of articles was again doubled up to 2012. Haunschild et al (2016) suggested that the growth of climate change literature is possibly induced by the increasing influence of the IPCC Assessment Reports, which eventually made climate change research a hot topic. The growth in our estimates of the climate change literature is in accordance with that estimated by Haunschild et al (2016). Our estimates are slightly lower though, because of our emphasis on precision i.e. use of relevant journals and the use of the "near" Boolean operator. Identification of the most prolific countries in the field shows the following production: USA 36.6%; England 10.9%; Germany 9.4%; China 7.5%; Canada 7.2%; Australia 6.8%; France 6.2%; Italy 4.4%; Japan 3.9%; Netherlands 3.9%. The European Union produced 43% of climate change research during 2015.

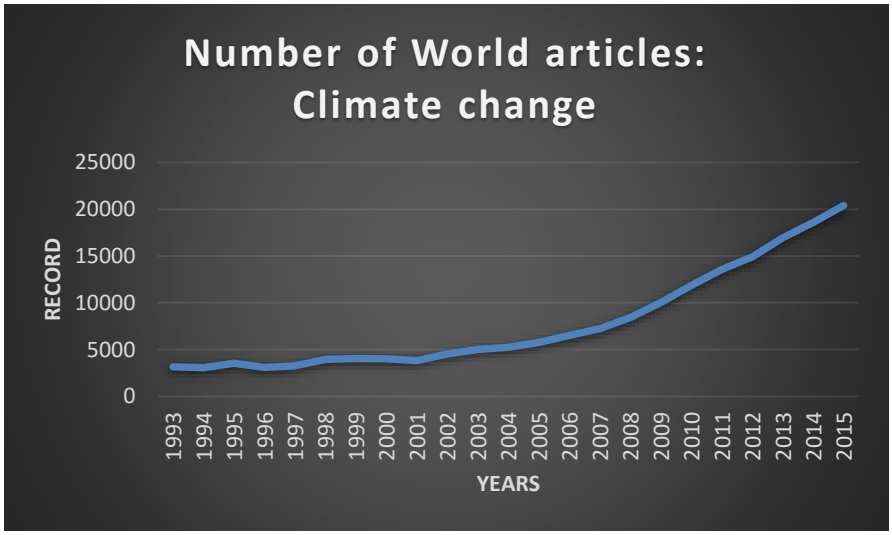


Figure 2: Number of World articles related to climate change 1993-2015.

Figure 3 shows the growth in the number of articles (all disciplines) with at least one author from the African Continent. The number of articles in WoS increased from 8269 during 1993 to 46908 during 2015. Again this is a substantial growth in comparison with the general growth of science. During the period the number of articles from Africa increased by a factor of 5.6.

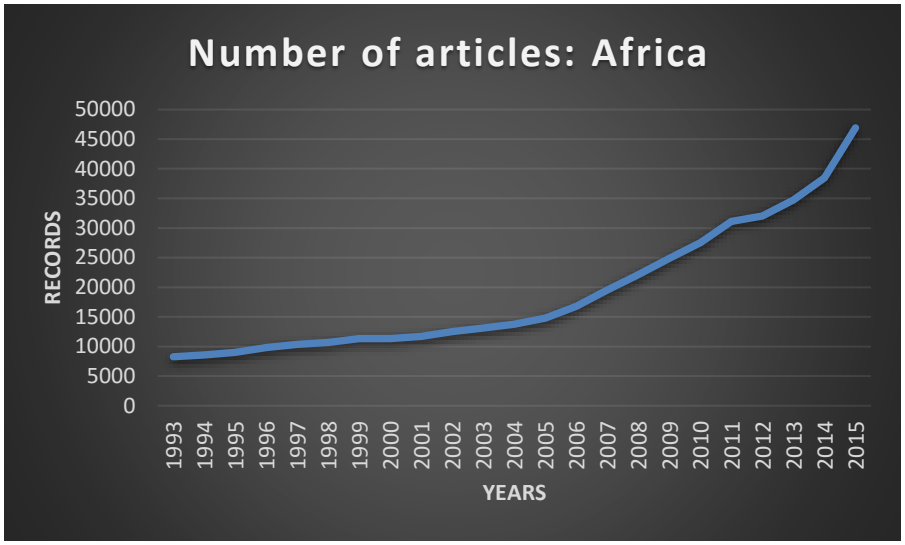


Figure 3: Number of articles from Africa 1993-2015.

South Africa is the most prolific African country having produced **31.8%** of the Continent's articles. Egypt (**21.4%**); Tunisia (**7.8%**) and Nigeria (**7.3%**) follow in the list. The most emphasised research areas are chemistry (**10.4%**); engineering (**7.6%**); physics (**7.2%**); and environmental sciences ecology (**5.6%**).

The main collaborating countries during the period are: USA (**12.9%**); France (**11.3%**); England (**7.3%**); Germany (**4.9%**); Canada (**2.7%**); Australia (**2.4%**); Netherlands (**2.4%**); Italy (**2.4%**); and Spain (**2.2%**).

It is important to re-emphasise here that **54%** of the African articles are produced with an international co-author and twenty-nine African countries published more than 90 % of their articles in collaboration with other countries (Pouris et al 2014). As we have argued this indicates a high dependency on international resources for research in Africa.

In contrast with Africa, Europe is the major producer of research internationally (**27.5%** of the World literature during 2013) and produces the majority of its research (**~75%**) without international partners. Europe's major partners are USA (**10.8%**); Canada (**2%**); China (**1.7%**); Australia (**1.67%**) and Africa (**1.6%**).

In the EU-Africa collaboration (134 180 articles over the period) the most prolific collaborative research areas were: Chemistry (**10.2%**); physics (**9.1%**); environmental sciences ecology (**6.5%**); engineering (**6.4%**) and infectious diseases (**5.5%**). Africa – EU collaboration increased from 1452 articles during1 993 to 14 608 articles during 2015.

Examination of the revealed priorities during the 1993-1997 and 2011-2015 periods shows that chemistry and physics were topping the list of priorities. In the earlier period the above scientific disciplines were followed by public environmental occupational health; materials science; tropical medicine and biochemistry molecular biology. During the most recent period the scientific disciplines following chemistry and physics were: environmental sciences ecology; engineering; science technology other topics and infectious diseases. It is emphasised that the increase in co-authorship is reflected in the majority of scientific disciplines.

The countries most often appearing in the collaboration list are: France; South Africa; England; Germany; USA; Tunisia; Egypt; Morocco and Algeria. The most often collaborating organisations are: Centre National de la Recherche Scientifique; University of London; University of Cape Town; Sorbonne Universites Comue; Institut de recherché pour le d développement; and University of Witwatersrand.

The most often mentioned funders (among the top 25 funders) are Wellcome Trust (3222); European Union/Commission/EU (2457); Medical Research Council (871); CERN (776); FCT Portugal (763) and National Research Foundation South Africa (1284).

Figure 4 shows the number of climate change articles with at least one author from Africa during the period 1993-2015. The number of relevant articles increased from 30 during 1993 to 872 articles during 2015. This is a 29 fold increase during the period. The European increase has been 8.3 fold during the period (from 1050 article during 1993 to 8812 articles in 2015).

During 2015 the activity index[3] of climate change research in Africa was 1.5. This means that Africa was undertaking 1.5 times more research related to climate change than what is expected by the Continent's total research outputs. The European activity index for 2015 was 1.3.

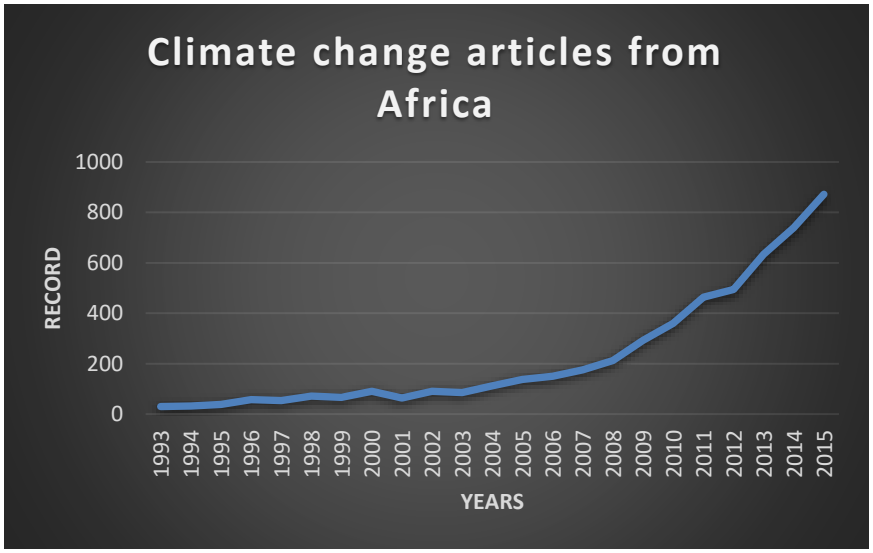


Figure 4: Number of climate change articles from Africa 1993-2015

Figure 5 shows the number of climate change articles that have at least one author from Africa and one from the European Union. The numbers have increased from below 10 articles in the early 1990s to 433 articles during 2015- a 43-fold increase. It is apparent (in conjunction with Fig. 3) that 46% of the African climate change articles were produced with at least one EU participant.

[3] The activity index is estimated as the ratio of the given field's share in the continent's publication output to the given field's share in world's publication output. An index of 1 indicates that the continent's research effort in the given field corresponds precisely to the world average.

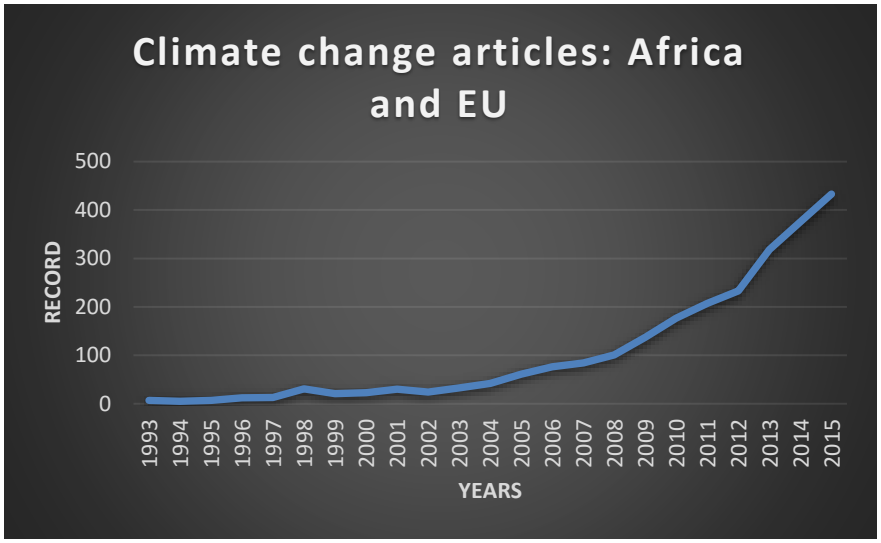


Figure 5: Climate change articles: Africa and EU in collaboration 1993-2015

Breakpoint test analyses of the data in figure 4 and 5 identify breaks in 2005, 2010, and 2013. The coincidence of the breaks in the two series is an indication that climate change research in Africa and in the collaborative efforts with Europe is led by the same forces.

Figure 6 shows the number of climate change related articles with authors from Africa but without European co-authors. It becomes apparent that there is almost equal number of relevant articles with European co-authors and without them.

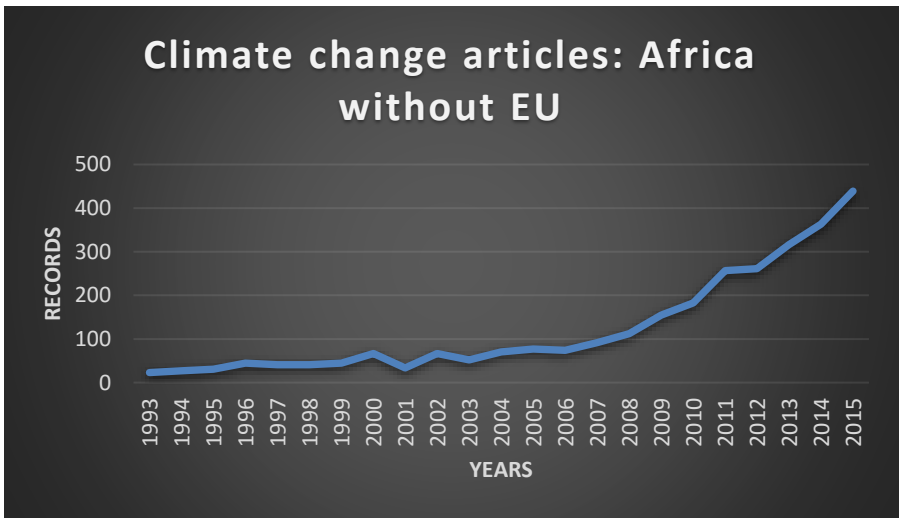


Figure 6: Climate change articles: Africa without EU 1993-2015

We investigated the overlap of African authors who publish on their own with those who collaborate with European partners. We focused on researchers who publish regularly in the field of climate change (at least ten articles during the period). This way we exclude transitory researchers who move in the field temporarily and then they move to another field (e.g. post-graduate students). We identified 38 researchers who had at least 10 articles on the field without European partners. All together they had published 572 articles during the period (20% of the total set). When we linked

their names with the African-EU collaboration we identified that these researchers had also published 91 articles with EU co-authors. It is apparent that the participation in a collaborative effort may have lasting effects even after the end of the initial project.

In order to estimate the effects of FP6 (2002-2006), and FP7 (2007-2013) on the number of articles, we estimated the growth in the period of the two programmes. The figures cover the period of the duration of each program plus one year in order to take into account the delay from the initiation of the support until the publication of the articles.

Table 2 shows the growth in the number of publications for the two programmes and the growth in all African articles during the period. The table shows that during the FP6 period (plus 1) the average discipline grew by 48.9%. The growth in the African climate change articles (without EU collaborators) it was 77%. However the growth in the number of articles with EU collaborators was 154% - twice as high as the growth in the articles without EU collaborators. Similarly, during the FP7 (plus 1) the growth in the collaborative articles with EU is substantially higher that the growth in climate change articles without EU collaborators. It should be noted that the growth rate during FP7 is substantially higher that during FP6 period. It becomes apparent that the FP 6 and FP7 had a positive and substantive influence in the production of co-publications in the field of climate change.

Table 2: Growth of climate change articles during the support of FP6 and FP7

Program	Growth in Africa+ EU climate change articles	Growth in African without EU climate change articles	Growth in African articles (all disciplines)
FP6	**154%**	**77%**	**48.9%**
FP7	**272%**	**182%**	**73.8%**

Table 3 compares the citation profiles of the African articles in climate change produced with and without EU collaboration. The table shows that climate change articles with EU collaboration perform almost twice better in terms of citations per article than the set without EU collaborators. Similarly, the H-Index of the collaborative set is higher than the index without the EU collaborators.

Table 3: H-Index and Citation comparisons of African climate change articles with and without EU collaboration

Set	H-Index	Average citations per article	Average citations per article without self-citations
African climate change articles (without EU)	**76**	**13.63**	**12.69**
Climate change collaborative articles: Africa and EU	**106**	**29.67**	**22.49**

We have investigated the funders (as they acknowledged by the authors) in the set of articles co-authored among African and EU authors. The European Union (in its various permutations European Commission, European Union; European Community etc.) was the most often mentioned funder. It was mentioned in 158 articles. The National Research Foundation (of South Africa) was the second

most often mentioned funder (73 times). The European Union was mentioned twice as often as the NRF which is probably the most important research funder in the Continent.

Other funders mentioned are the National Science Foundation (USA); the Leverhulme Trust; Wellcome Trust and others. It should be mentioned that other European organisations (CNRS; DAAD; academy of Finland etc.) appear in the list.

More detailed analysis revealed that during the FP6 period funders were identified only in limited occasions. The majority of the EU funding appeared during the FP7 operation (129 references). It should be emphasised that of importance is the relative frequency of references to particular funding source.

In the list of climate change articles without EU collaborators the most often mentioned funder is the National Research Foundation (210 times). The National Science Foundation (USA) follows with 36 references. A number of South African Universities are also in the list. It interesting to mention, that there are no other African sources of funding among the top 50 funders in terms of frequency.

We have also examined the production of relevant research of the geographic regions in the Continent. Table 4 shows the number of articles of each region; their H-Index and average number of citations per article.

Table 4: Regional production of climate change articles 1993-2015

Region	Number of articles	H-Index	Average citations per article
Southern Africa	2542	96	28
East Africa	1347	79	22
North Africa	836	43	13
West Africa	813	45	13
Middle Africa	162	27	20

Articles from Southern Africa attract higher citations on average. Middle Africa has the smallest number of articles during the period.

8. Discussion and Recommendations

Climate change research started receiving international attention in the early 1990s and is one of the top priorities in the bi-regional cooperation between Africa and EU.

The literature (CAAST-Net Plus 2016; CAAST-Net Plus 2014) identifies the asymmetry in capabilities between Africa and Europe and the weakness in uptake of research findings by policymakers in Africa. Implicit in the relevant literature is the lack of recognition of the importance of science and research by the political authorities in Africa.

Similarly Pasgaard et al (2013) identified a North–South divide between exposure to risk, vulnerability and available knowledge. They argued that published research on countries which are assessed at high climatic vulnerability is lower than countries with less vulnerability.

Africa is a scientifically small Continent. Its scientific contribution has increased from 1.4% of the world scientific literature in the 1990s to approximately 2.6% in the current decade but it is still very small particularly if the size of population is taken into account.

Collaborative research as it is manifested in co-authored articles including African researchers has increased substantially since 2003. Individual African countries exhibit substantially higher collaboration patterns than the rest of the World.

The estimated 29 fold increase in the number of African climate change articles during the 1993-2015 period (well over the 5.6-fold increase of all disciplines articles from Africa) also supports the advanced argument that availability of resources fuels collaboration and increase in research outputs.

The analysis shows that collaboration is a critical factor in the development of research systems in Africa. Fifty four percent of the African articles are produced with an international co-author and twenty-nine African countries publish more than 90 % of their articles in collaboration with other countries. It interesting to mention, that the collaboration share in India is 20 %; in China 23% and in USA 33%.

The Africa-EU collaboration contributes 30% of the total research output of the African Continent. While it is difficult to estimate the counterfactual – what would have happened without the EU collaboration – it can be argued that at least for a number of African countries, lack of international support will have devastating effects for their research systems.

The analysis shows a 10-fold increase in the co-authorship set (all disciplines) between Africa and Europe during the 1993-2015 period. The disciplines emphasised during the period are chemistry and physics (approximately 20% of the co-authorship set).

The literature review identifies that there are a number of forces that lead to collaborative research internationally (easiness of communications; growth of big science etc.). Apart of the international forces leading to collaborative research, availability of resources appears to lead to collaboration in Africa. This line of argument can explain the across all the African countries increase in collaboration, the preference for non-African collaborators and the emphasis on research disciplines of interest to international partners. Local historical and cultural characteristics and the small size of African countries (smaller countries may have smaller single country publications due to the scarcity of collaboration opportunities at the national level) are additional factors superimposed on the phenomenon. Certain researchers even suggested that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries.

There is substantial evidence that internationally co-authored papers tend to have on average higher citation rates. However, there is also evidence that when scientifically advanced countries collaborate with scientifically less advanced countries, the outcome may affect negatively the citation rates of the advanced country. The analysis of African climate change research shows that climate change articles with EU collaboration perform almost twice better in terms of citations par article than the set without EU collaborators. Similarly the H-Index of the collaborative set is higher than the index without the EU collaborators.

In summary it is evident that EU collaboration is critical for Africa both in terms of research activity and citation impact. An issue that is of importance is related to research priorities. International partners may not always have the same priorities as the local system and may misdirect the local researchers. This is a critical issue that should always be in the radar of African authorities.

Investigation of the funders, as they acknowledged by the authors, in the set of articles co-authored among African and EU authors reveals the importance of EU in funding. The European Union (in its various permutations European Commission, European Union; European Community etc.) was the most often mentioned funder. It was mentioned in 158 articles. The National Research Foundation (of South Africa) was the second most often mentioned funder (73 times). The European Union was mentioned twice as often as the NRF which is probably the most important research funder in the Continent.

Other funders mentioned are the National Science Foundation (USA); the Leverhulme Trust; Wellcome Trust and others. It should be mentioned that other European organisations (CNRS; DAAD; academy of Finland etc) appear in the list. It is emphasised that the frequency of acknowledgements are indicative of the relative importance of funders.

More detailed analysis revealed that during the FP6 period funders were identified only in limited occasions. The majority of the EU funding appeared during the FP7 operation (129 references) as the funding increased. For example the EU contributions to South Africa increased from EUR 3.3 million during FP4 to EUR 6.5 million during FP5 to 16.2million during FP6 and to EUR 33.1 million during FP7 (EC 2016).

The Climate Policy Initiative (2016) identified that during 2014 the global climate finance was USD392 billion, up from USB 342 billion during 2013. USD 241 billion was private money and USD 336billion was spent for mitigation.

In this context it should be repeated that climate change will receive substantial funding (as much as €180 billion) during 2014-2020.

Table 5 shows the emphasis on climate change research in a number of regions as it is manifested in the ratio of climate change articles published during the period as a percentage of total publications during the period. Africa devotes 1.2% of its research on climate change while China, India and Brazil devote only 0.4% of their research on the field.

The prioritization in collaboration affects the local priorities due to the small size of the African research system. This is a critical issue for the African Continent.

Table 5: Climate change research emphasis: selected regions

Country	Total publications 1993-2015	Total climate change articles 1993-2015	Ratio: climate change to total
Africa	439 381	5 323	1.2%
Europe	8 256 379	77 334	0.9%
Australia	1 069 319	12 420	1.1%
USA	11 724 345	66 340	0.5%
China	3 044 402	17 314	0.4%
India	911 868	3828	0.4%
Brazil	753 048	3084	0.4%

The increase in the climate change articles took place mainly during the times of the operations of FP6 and FP7. There was minimal research on the topic prior to 2000s. Table 6 shows the increase in the African articles (all disciplines); climate change articles from Africa (without EU partner) and

climate change articles produced in collaboration between Africa and Europe. The growth rates are revealing.

Table 6: Growth of climate change articles during the support of FP6 and FP7

Program	Growth in Africa+ EU climate change articles	Growth in African without EU climate change articles	Growth in African articles (all disciplines)
FP6	154%	77%	48.9%
FP7	272%	182%	73.8%

Finally identification of the climate change articles according to geographical location in Africa shows that Southern Africa and East Africa are the major producers of climate change research.
The above lead to following recommendations:

- The CAAST-Net and CAAST-Net Plus supported by the Framework Programmes appear to have been successful in encouraging more and better bi-regional STI cooperation for enhanced outcomes related to climate change. The success is particular important as Africa had limited, if any expertise, in the field in the 1990s. It is suggested that similar approaches can be utilised to develop research capacity and cooperation in other fields of common interest and priority.

- The collaborative patterns in a variety of African countries reveal dependency of the local research systems on international resources. Furthermore, the high degree of collaboration indicates that there might be limited scope for additional expansion. African governments, multilateral organisations and their international partners should focus in developing research capacity. Providing funding rewards for research publications has been proven effective in South Africa (Pouris 2012) and can be used across the Continent.

- The small scientific size of Africa and of African countries makes the issue of research priories of critical importance. Prioritization is required across the broad main domains (e.g. environment versus health versus manufacturing) and within each domain (e.g. local effects and mitigation versus global effects of climate change). The field of foresight has been identified to be useful in that domain. National and regional exercises can introduce the concept to the relevant authorities. Countries with expertise in the field with the support of multilateral organisations and the African partners can lead in the effort. Such exercises could also guide the European Commission in enhancing its collaborative efforts with Africa.

- The sub-critical size of research systems, lack of funds for co-financing and dependence on international resources are manifestations of the refusal or neglect of African governments to accept that innovation is the fundamental cornerstone of economic growth, employment, international competitiveness and development. African governments, multilateral organisations and their international partners should aim to institutionalize the governance and support of science, technology and innovation. The establishment of high level Ministerial Committees responsible for the management of the innovation systems (as in Korea, China and elsewhere); the establishment of extra-budgetary funds for research and the institutionalisation of relevant advocacy activities are possible approaches to be followed.

9. References

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