Journal of the Knowledge Economy
https://doi.org/10.1007/s13132-026-03180-7

A Scientometric Analysis of Science Outputs and the Political Economy Undergirding Science in Southern Africa

Pfungwa M. Nyamukachi[1] · **Anastassios Pouris**[1]

Received: 18 October 2023 / Accepted: 23 January 2026
© The Author(s) 2026

Abstract

This paper examines scientific knowledge production in the Southern Africa Development Community (SADC) region over the period 2000 – 2022. Research productivity in the region is uneven, with South Africa contributing the majority of outputs, while other member states are marginal contributors. Health related fields account for the largest share of publications, followed by agriculture/environmental sciences, with engineering, energy and applied sciences underrepresented. Research collaboration is largely external, oriented toward Europe and the United States, while intra-African collaboration still limited. Structural challenges, including persistent underinvestment in research and development; weak research infrastructure, and human resource constraints, limit research efforts and research sovereignty. The study combines bibliometric analysis with an examination of the political economy of science, providing an integrated perspective rarely applied in regional analyses. By highlighting the critical role of sustainable domestic funding for research, talent development and stronger regional collaboration—the findings underscore the pressing need for policies to build more resilient and sovereign African research systems aligned with national and regional development goals.

Keywords SADC · Africa · Knowledge production · Bibliometrics · Scientometrics · Research sovereignty

✉ Pfungwa M. Nyamukachi
pfungwanyamukachi@gmail.com

Anastassios Pouris
apouris@icon.co.za

[1] Graduate School of Technology Management (GSTM), University of Pretoria, Pretoria, South Africa

Published online: 02 March 2026

Introduction

The African Union's adoption of the Science, Technology and Innovation Strategy for Africa (STISA–2024) (AU, 2014) emphasises the roles of research, technology and innovation as critical enablers for achieving the continental development goals. According to STISA, social transformation and economic competitiveness are enabled through human capacity development, industrialisation, entrepreneurship and innovation. The establishment of the African Observatory for Science Technology and Innovation (AOSTI) to track, monitor and evaluate knowledge production and innovation systems on the continent reflects ongoing continental efforts to restructure and strengthen its research and innovation systems.

These continental policy drives, together with science and technology commitments at country and regional level through the establishment of science funding agencies, which manage the allocation of funding for research and innovation signal that research and innovation are recognised as key drivers of development (Science Granting Councils, n.d.; Pouris & Pouris, 2011).

To meaningfully support all these continental ambitions, a systematic understanding of the research and innovation ecosystem is essential. The paper discusses the ecosystemic factors that enable or constrain knowledge production in the Southern Africa Development Community (SADC) region. Although bibliometric and scientometric analyses are gaining considerable traction in academic literature, serving to map, evaluate, and characterize scientific and innovation activity, there remains a notable gap in regionally focused studies on Southern Africa. Existing scholarship has primarily concentrated on national-level assessments (Leonard et al., 2022) or broader continental analyses. Additionally, several bibliometric studies have examined disciplinary trends in isolation, with limited attention to inter- or intra-regional dynamics. For instance, Leonard et al. (2022) conducted a national-level study on Namibia, while Kiwelu et al. (2023) explored biomedical research productivity across sub-Saharan Africa. Similarly, Heleta and Jithoo (2023a, b) investigated collaboration trends within South African universities. Despite these contributions, there is limited research integrating bibliometric analyses with the socio-political economy of science, highlighting an underexplored area in the literature.

This paper contributes to addressing this regional gap. It uniquely combines a quantitative bibliometric analysis with a qualitative socio-political economy assessment of the region's science system. This integrated approach provides a robust, evidence-based framework for interpreting trends and informing policy recommendations.

The Southern African Development Community (SADC) is a regional block established in 1992 under Article 2 of the SADC Treaty. Its vision is to leverage on the strengths of the region and has as its vision to be "an efficient and responsive enabler of regional integration and sustainable development". The SADC member states are: Angola, Botswana, the Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland/Eswatini, United Republic of Tanzania, Zambia and Zimbabwe. The newest member state is Comoros, however Comoros was not included in this study because it is a recent addition to SADC and was not influencing the region in the past. In addi-

tion, in terms of bibliometric data, it is a small country with very little representation in the Web of Science database.

This paper has two overarching aims. First, it seeks to analyse the state of the ecosystem for science in the region using a socio-political economy lens to understand the structural enablers and constraints. Second, it presents a longitudinal bibliometric analysis of the region's outputs from 2000 to 2022 across 15 SADC member states. In doing so, the paper responds to a gap in literature in that although bibliometric and scientometric studies on Africa are growing, they are often descriptive, focussed on single countries or disciplines, and rarely integrated with political economy analysis. By integrating bibliometric data with an eco-systemic perspective, this study contributes to a more holistic understanding of knowledge production in Southern Africa and the implications for research sovereignty and regional integration. Guided by these aims, the analysis addresses the following questions:

1. What structural, institutional and socio-political factors enable or constrain knowledge production in the SADC region
2. What are the publication trends in the SADC region over the past two decades?
3. Which research fields dominate knowledge production in the region and which are under-represented?
4. What are the patterns of collaboration in the SADC research outputs?
5. Who are the cited funders of research in the region?

This paper is structured as follows, Section "The Socio-Political Economy Undergirding Research and Knowledge Production in the SADC Region" analyses the ecosystem undergirding science and knowledge production systems in the SADC region. Section "Bibliometric Methodology, Objectives, Data Source, Timeframe and Limitations" outlines the bibliometric methodology followed by this study. Section "Bibliometric Findings, Qualitative Discussion and Recommendations" presents the key findings of the bibliometric analysis and recommendations. Finally, Section "Conclusion and Recommendations" offers the conclusion.

The Socio-Political Economy Undergirding Research and Knowledge Production in the SADC Region

While the importance of research and innovation for development is widely acknowledged in continental frameworks (e.g. STISA, 2024), the actual capacity of countries to deliver on these ambitions is shaped by a range of structural and contextual realities. This section asks what structural, institutional and socio-economic and political factors enable or constrain knowledge production in the SADC region. This to provide the contextual foundations necessary for interpreting the bibliometric patterns analysed later in the paper.

Conceptual Frameworks for Understanding the Socio-Political Economy of Research and Knowledge Production

Kahn defines the political economy as the "interaction among society, politics, culture, and the economy" (Kahn, 2022a, b). In this study, this definition is useful in understanding the ecosystem of role players/actors, institutions, governance structures and economic factors that undergird and shape knowledge production and influence the broader knowledge economy. Kahn's definition is particularly relevant to research and scientific activity, because it highlights that science systems don't operate in a vacuum. The SADC region's knowledge production sector is shaped by national capacities – human and financial – and also by historical and political legacies. For example, the shared histories of colonialism continue to influence present-day social, economic and institutional dynamics which in turn affect scientific activity and collaboration patterns.

Similarly, Castells (2000) argues that all knowledge economies are part of systems that are networked. Understanding these networks is important for grasping how knowledge is produced, circulated and utilised. The concept of national innovation system (NIS) similarly provides a framework of understanding the various components, institutions, policies and resources that contribute to the performance of science and innovation systems (Lundvall, 1992). These frameworks guide the analytical approach of this paper.

Historical and Contemporary Factors Influencing Science Ecosystems in Africa

The institutional legacies left by colonialism contribute to the current state of science and innovation systems in Southern Africa. At independence, SADC countries inherited colonial universities and research systems that were modelled on European institutions and systems that were disconnected to local needs and lacked a true transformational, development agenda for the greater citizenry (Wangui, 2024). Post-independence various efforts have been made to restructure these science systems and institutions. However, progress is impeded by a number of reasons that include weak linkages or co-ordination between stakeholders, a disconnect between research activity vis-a-vis local needs and chronic under-funding in science and innovation. As a result, many countries in the region rely heavily on external funding (Kahn, 2022a, b; Tijssen & Kraemer-Mbula, 2018; Gaillard & Mouton, 2022).

In addition to these systemic and historical reasons, contemporary political and economic conditions also influence research ecosystems. Economic fragility, governance deficits political instability, unrest and military events can hinder long-term scientific development. Granted, the SADC region has largely been war-free and peaceful for the past five to 10 years. Political uncertainty prevails for example in Zimbabwe where the economy is in malaise and the country regarded as a fragile state. The IMF defines fragile states as "States in which the government is unable to deliver basic services and security to the population face severe and entrenched obstacles to economic and human development … fragile states generally have a combination of weak and non-inclusive institutions, poor governance, low capacity, and constraints in pursuing a common national interest. As a result, these countries

typically display an elevated risk of both political instability (including civil conflict), and economic instability (through a low level of public service provision, inadequate economic management, and difficulties to absorb or respond to shocks) affecting all aspects of social life including education and research" (IMF, 2015:7).

In the SADC region, the IMF's resilience map identifies Zimbabwe, the DRC and Madagascar as falling within the fragile red zone category. These conditions certainly shape and often constrain the functioning of research and innovation eco-systems.

To account for these variations and unpack what they mean for research and innovation systems, Kramer-Mbula and Scerri (see UNESCO, 2015) classify the Southern African countries into three groups based on the strength of their research and innovation systems:

- **Fragile innovation systems:** Democratic Republic of Congo (DRC), Lesotho, Madagascar, Swaziland, Zimbabwe.
- **Viable innovation systems**: Angola, Malawi, Mozambique, Namibia, Seychelles, Tanzania, Zambia.
- **Evolving innovation systems:** Botswana, Mauritius and South Africa.

This typology highlights the disparities in science system capacity across the region and also the need for differentiated policy responses to address each country's challenges.

Key Structural Inputs that Shape the State of Research and Knowledge Production in SADC

As a start, to frame the regional context it's worth noting that as a region SADC countries together have a combined GDP of $721.3 billion, and the region registered a growth rate of 1.8% in 2018 – a decline from the 2.1% rate of 2017. In terms of population, the SADC region in 2018, was home to approximately 350 million people with the DRC hosting the largest population percentage accounting for 26.6% of the total, followed by South Africa that makes up 16.7%, and Tanzania 15.7% (SADC RISDP Report 2020–2030). The SADC region contributes nearly a quarter of Africa's GDP and economically the top three countries in the region are Angola, South Africa and Tanzania that make up ± 73% of the region's GDP (UNESCO Science Report, 2021).

In terms of governance, SADC has as one of its cornerstones for socio-economic growth, science, technology, and innovation (STI). Besides Comoros, 14 of the member states now having STI policies in place, and a majority have dedicated government departments responsible for STI, as well as specific institutions assigned to fund and implement STI programmes. SADC has also adopted a Regional Intellectual Property Rights Framework and Guidelines which was adopted by the Council of Ministers in 2018 (SADC RISDP Report 2020–2030).

All these developments are positive and an indication of how SADC as a region are prioritising and seeking to put in place the required governance i.e. legislative, and institutional instruments to better support STI efforts and to build the region's knowledge economy. This in line with the Science, Technology and Innovation Strat-

egy for Africa (STISA) which was adopted at the 23rd AU Summit in Malabo in June 2014. The STISA Strategy forms part of AU Agenda 2063, which outlines the need to 'consolidate African initiatives and strategies on accelerated human capital development, science and technology and innovation, with a focus on issues related to Food Security, Built Environment, Water and Energy.' (NEPAD, n.d.)

As it relates to research and knowledge production, there are several science, technology, innovation (STI) input factors that are important to track and analyse. These include: funding for research (e.g. government spending on research (GERD), business expenditure for research (BERD), research priorities, science governance structures, and policy frameworks, institutions for science (e.g. number of doctoral enrolments, number of universities and research institutes, government departments responsible for research and innovation), academic freedom, accessibility of scientific outputs, research talent/human resources (i.e. aspects such as researcher FTE/million count and ratios; gender ratios of research staff), research infrastructure, research collaboration amongst other factors (Kahn, 2022a, b).

This study focusses on a subset of these factors and they are summarised in Table 1 below and discussed in sections that follow. The four key structural input factors that undergird the performance of science systems and influence knowledge production in the region.

Table 1 presents four key structural input factors that influence national research capacity, namely: population size; gross domestic product (GDP) as an indicator of the size of the economy; Research funding measured through gross expenditure on research and development (GERD); and the number of fulltime equivalent researchers (FTE) researchers. Together these factors shape and influence research capacity i.e. the performance of science systems and knowledge production in the region. As

Table 1 Structural input factors for research and knowledge production

Country	Population (million)	GDP (USD Billion)	FTE researchers per million inhabitants (UNESCO IS 2015)	GERD 2018 or closer (UNESCO Science Report, 2021)
Angola	31 825	67.40	73	0.03
Botswana	2 304	17.61	344	0.54
DRC	86 791	55.35	206	0.41
Eswatini	1 148	4.74	-	0.27
Lesotho	2 125	2.50	21	0.05
Madagascar	26 969	14.47	109	0.01
Malawi	18 628	12.63	123	-
Mauritius	1 266	11.53	285	0.35
Mozambique	30 366	15.78	66	0.34
Namibia	2 495	12.31	-	0.34
Seychelles	98	1.45	-	0.22
South Africa	58 558	419	818	0.61
Tanzania	58 005	67.84	69	0.51
Zambia	17 861	22.15	49	-
Zimbabwe	14 645	28.37	200	-

World Data, n.d.; UNESCO IS; UNESCO Science Report, 2021

the data reveals, there are wide disparities across the SADC member states, which are discussed in detail in sections that follow.

Population and Research Talent

In terms of population size, the three most populous SADC countries are the Democratic Republic of Congo (DRC), South Africa and Tanzania. A larger population indicates a larger potential talent base to produce more researchers which can thus more scientific outputs. Whereas smaller countries like the Seychelles and eSwatini may struggle to build a critical mass of research/scientific talent and would need to develop more targeted strategies and investments in certain niche research areas. The relationship to science production is not straightforward as depends on how much of the population is engaged in research activities and the quality of the educational and research infrastructure.

A more important factor is the number/density and quality of researchers in the research and knowledge production system and this is measures as the number of full-time equivalent researchers (FTE) per million inhabitants. Research requires a cohort of highly qualified research personnel in the higher education and research sector (Whitworth et al., 2008:1590). In Africa, the average number of researchers per million of population is low, the number is about 200 researchers per million, yet the global average is approximately 1,150 per million (Mohamedbhai, 2024).

The number of researchers directly contributes to the amount of scientific work produced. More researchers typically lead to more publications and other scientific outputs (OECD, 2015, p. 162). Insufficient numbers of researchers can have a negative impact on research productivity and research outputs. SADC and Africa broadly faces a talent challenge in the research system.

Within SADC countries, in terms of FTE researchers per million South Africa leads by a wide margin, followed by Botswana, Mauritius, the DRC and Zimbabwe as per UNESCO data (UNESCO, 2015). The other SADC countries are underresourced and this talent gap must be addressed to enhance scientific capacity.

Doctoral enrolments are also an important indicator to track to ensure that a scientific research system will be adequately staffed in future. A study of doctoral enrolments at eight universities in Africa between 2001 and 2011 revealed a dismal picture (Bunting et al., 2014: 22).

Although there have been increases in doctoral enrolments over the period, the numbers are significantly low to meet the market needs of Africa. A Bunting et al. doctoral enrolment study (2014), analysed eight universities—University of Botswana, the University of Cape Town, the University of Dar es Salaam, Eduardo Mondlane University, the University of Ghana, the University of Mauritius, Makerere University and the University of Nairobi. The study revealed that in 2001, the total combined doctoral student enrolment of the eight universities was only 1 165 and of 706 (or 61%) of the students were enrolled at the University of Cape Town. In 2007, the total number of doctoral enrolments at the same eight universities was 1 633 and again, students at the University of Cape Town constituted 61% of the total (Bunting et al., 2014: 11—22).

An ageing professoriate, brain drain with academics leaving Africa in search of greener professional pastures also contribute to the staffing challenge. A study sponsored by the Research and Development Forum for Science-Led Development in Africa (RANDFORUM) revealed that as much as 30% of African scientists leave the continent. Reports by the Economic Commission for Africa and the International Organization for Migration (IOM), similarly note the magnitude of the brain drain (Beaudry & Mouton, 2018: 24).

Increasing the participation of women and girls in all educational levels is critical and will also help plug the talent gap. According to the UNESCO Science Report just under one in three (30%) researchers in sub-Saharan Africa is a woman UNESCO, 2021).

GDP and GERD in Southern Africa

Gross domestic product (GDP) is a measure of the size of an economy and the level of economic activity in a given country. In terms of science systems, GDP can give an indication of what the public purse can afford and offer towards the funding scientific activities. In this regard, South Africa is the largest economy in the SADC region by manifold.

The gross expenditure on research and development (GERD) is an important factor because it measures expenditure on research and this funding is what facilitates and enables research activities. Lack of funding affects all aspects of the research process such as research infrastructure and ability to employ research talent and experts. GERD comprises the expenditure or spend by businesses, governments, universities, research institutions, philanthropic agencies and also contributions by private non-profit organisations (UNESCO, 2015: 496).

The gross expenditure on research and development (GERD) ratios presented in Table 1 above were based on the UNESCO Science Report, however, for South Africa, more recent data reflects that the latest reported GERD has declined and now stands at 0.61% in 2020/21 (NACI, 2023). South Africa's GERD is followed by Botswana, Mauritius and Tanzania whose GERD ratios exceed 0.50 even though their GDP, population and researcher densities are marginally different and much smaller.

Even though South Africa has the highest GERD ratio, this is still less that the 1% of GDP target. Nonetheless, South Africa is the GERD leader. It has a more robust national innovation system than its other SADC counterparts which is reflected in the fact that South Africa accounts for 96% of all patent filings in the region between 2008 and 2013 (UNESCO, 2015: 30, 496).

GERD by funding sector—Governments are not the only sources of funding for R&D. The business sector also contributes through its investments in research and development activities. An analysis of G20 countries in 2013 conducted by the OECD, revealed that G20 countries invest heavily in R&D, with investments to the tune of billions. GERD ratios for the United States, China, France, Canada, and the European Union are all above 1.5% of GDP. For economic giants, such as the United States and China, R&D expenditure is ± US$100 billion. Notably, for Asian countries such as Japan, Korea and China, their business sector funds over 70% of R&D expen-

diture. And for the United States and the European Union countries industry/business expenditure accounts for more than 50% (OECD, 2016).

The source of research spend, i.e. government funding vs. business funding, is an important factor when analysing GERD and African countries can learn from other countries on this point. Research has shown that the more developed an economy, the larger the share of research spend from the business sector as opposed to government. Business R&D expenditure (BERD) is also often for applied research and is used to develop new products and processes which drives economies and creates jobs. The relationship between R&D intensity and business financing of R&D expenditure suggests that high levels of economy wide R&D investment are not attainable without a strong private sector commitment (OECD, 2016:6).

The business sector in South Africa has historically contributed significantly as a funder of research and development. For example, in 2001, the business sector contributed 53.3% of total R&D expenditure and in 2008, the business sector R & D expenditure peaked at 58.6%. However, this expenditure has been declining since then, in 2009, the business sector's spend on R &D fell to 52.9. This was attributed to the 2008 global financial crisis and also "the partial demise of several large companies which were responsible for the bulk of the BERD e.g. Anglo-American, Eskom, the movement of local R&D to other countries (such as was the case with De Beers and others), and the closure of the Pebble Bed Modular Reactor in 2014 was reported at 45.4%" (NACI Review, 2017a, b:20–21).

Recent assessments of BERD in South Africa reveal that it declined further in 2020/21. In addition, "the business sector's capacity to attract foreign funding is declining overall and as a share of foreign funding. Within the business sector, there is no indication of any major areas that are exhibiting a notable technological dynamism or a sustained rise in their share of R&D. Alternative funding mechanisms, including international investment, are also needed to promote a smarter mix of funding that embraces the participation of several stakeholders in using STI to address various sustainability issues" (NACI, 2023).

A more diversified mix of R & D funding that includes government, private sector, international and philanthropic funding would be reverse the decline.

Broader economic performance also affects both GERD and BERD. Unfortunately, the African Development Bank highlighted structural income stagnation across the continent and an unchanging income class structure between 1980 and 2010 especially in the poor class and the rich class. As of 2010, 60% of the population was still falling within the poor class (AFDB, 2015).

Across the board African economies have failed to shift significant numbers of citizens from the poor class into the middle class. This has an impact on available resources that can be directed to research and innovation as there are many other competing social priorities.

The UNESCO Science Report in 2021 similarly shows that this bleak and stagnant economic performance in the Southern Africa region for the period between the years 2014–2019. Based on the UNESCO Science report, within the SADC region, Zimbabwe reports the steepest decline economically negative −8% which impact regional average. This economic decline has certainly had an impact on infrastructure and by extension the Zimbabwe education and science system. In the region, Angola

and Namibia also reported negative growth. The rest of the region achieved single digit growth, with Tanzania achieving the highest at 5.79% in 2019. As a region GDP growth has been low, averaging only 2% between the years 2014–2019. This certainly has ripple effects that include negative impacts on the funding of science and funding of the wider education and innovation ecosystem (UNESCO Science Report, 2021).

Such slow or negative growth, inevitably results in limited R & D budgets, weakening the ecosystem. The effects of underfunding are profound. Beaudry and Mouton (2018) similarly lament this state of neglect of science systems in Africa, and refer to it as the "de-institutionalisation" of science. "De-institutionalised science systems exhibit a number of characteristics, namely weak, unsupported institutions, financially and from a policy standpoint. De-institutionalised science systems, as a result of unavailability or insufficiency of government support, show a high reliance on international or external donors to fund research activities, as well as an individual focus opposed to building sustainable networked or integrated institutions for science and innovation. All of these factors lead to the "Inadequate reproduction of the scientific and academic work force (decline in the number of doctoral programmes and doctoral students) and weak inscription of science in African societies" (Beaudry & Mouton, 2018:21). Such systems cannot sustain long-term resilience, innovation and competitiveness.

Higher investments and funding for R&D correlate with stronger science systems with increased science outputs. This is because more funding is catalytic and enables the procurement of better research facilities, equipment/infrastructure, and higher salaries to attract talented researchers, and thus increase productivity, research outputs and support for innovations that may come from R & D.

Without the requisite investments, particularly domestic investments and greater private sector investments, SADC will remain reliant on external funding. They will continue to struggle to build robust, resilient research systems needed to support sustainable development.

The preceding analysis of the political economy of science in the SADC region highlights significant structural conditions such as disparities in research funding, human resource capacity and research infrastructure – that shape knowledge production in the region. To complement this contextual perspective, the study now employs a bibliometric analysis to examine how these systemic dynamics are reflected in research outputs, fields of specialisation, collaboration networks and research funding patterns. The next section outlines the bibliometric methodology, providing the integrated framework through which the drivers, outputs and patterns of scientific knowledge production in the SADC region can be assessed.

Bibliometric Methodology, Objectives, Data Source, Timeframe and Limitations

Science systems do not operate in isolation, and Section "The Socio-Political Economy Undergirding Research and Knowledge Production in the SADC Region" sought to set the scene and discussed some of the direct factors that shape research

capacity in the SADC region – these are factors that also influence bibliometric outputs. Bibliometric outputs include journal articles, books, reviews, patents and any written forms of academic/scientific output produced by scientists and researchers – are used as proxies for research activity and knowledge production (Pouris, 2015; Hayatdavoudi et al., 2023; Pouris, 2010).

Bibliometric data analyses are a widely used quantitative method for assessing research productivity. They are considered an objective tool of assessment and have grown to be a well-developed scientific discipline with its own journals e.g. Scientometrics, Journal of the Knowledge Economy, the International Journal of Scientometrics and many others dedicated to this interdisciplinary field. However, bibliometrics have challenges and limitations. The most common limitations relate to data quality and data availability (Hayatdavoudi et al., 2023). Data is not always available and where data may be available, bibliometric analyses are also limited in terms of data quality as spelling errors, be they errors spelling author names, word spelling errors and inaccurate spelling of institutional names can easily swing the numbers. Also, bibliometrics may not capture the diverse range of research outputs for example within the artistic outputs (Costas et al., 2010, and similarly Kahn et al., 2019; University of Waterloo Working Group on Bibliometrics, 2016). These limitations must be kept in mind when interpreting findings.

Limitations—Cultural Considerations Pertinent to this Study

In the African context, in addition to the above bibliometric studies face additional challenges related to database coverage and language bias. Many local/African journals are under-represented or absent from the major databases such as Web of Science and Scopus. Furthermore, publications African or non-English are not indexed or comprehensively covered in these databases (Pouris & Ho, 2014).

Although cultural factors were not the main focus of this paper, however they are important in order to understand the dynamics of knowledge production in Africa. The two critical cultural aspects that are pertinent to this study – epistemological inclusion/exclusion and language.

With regards to epistemological aspects, it's important to acknowledge that research and knowledge production isn't siloed to journals and scientific publications and not the exclusive domain of only academics and university scholars. Given that Africa is the cradle of humankind, it is also the cradle of knowledge. Before colonization, African societies had developed complex and sophisticated knowledge systems that successfully sustained them for generations. This indigenous knowledge was deeply embedded in the cultural, social, and environmental contexts. Sillitoe defines indigenous knowledge as "Indigenous knowledge (IK) is any understanding rooted in local culture that may not be documented but valuable nonetheless. IK includes all knowledge held more or less collectively by a population that informs interpretation of things. It varies between regions. It comes from a range of sources, is a dynamic mix of past 'tradition' and present invention with a view to the future" (Sillitoe, 2006). Unfortunately, the epistemological legacy of colonization in Africa has meant that western epistemologies dominate and are considered credible science, relegating indigenous knowledge to the periphery and sidelined (Fon Tata et al., 2023). Yet,

there is value and power in epistemic pluralism. Epistemic pluralism is a concept "concerned with democratising knowledge and acknowledging that there are many ways of knowing" (Ndlovu-Gatsheni, 2018). Fon Tata et al. contends "the continent's rich tapestry of indigenous knowledge, when woven seamlessly with Western paradigms, has the potential to catalyze innovation, address pressing challenges, and empower communities. In embracing this transformative journey, Africa beckons toward a future where diverse knowledge systems coexist harmoniously, contributing to the continent's development and global progress". Harmonizing indigenous and western knowledge could help catalyze innovation and offer context-specific solutions to African challenges.

The other cultural aspect that is important to consider is language. Scientific discourse and dissemination remains overwhelmingly dominated by the English language (Wilmot et al., 2023). Africa accounts of one third of languages in the world, yet "research published in languages other than English, often have limited options for publication" leading to "inequalities in knowledge production and dissemination….Non-English language publications are less likely to be cited by other scholars, which leads to a reduction in the impact and recognition of African research by global academic communities" (Aldirdiri, 2024). Thus much of Africa's publications remain un-indexed by many of the bibliometric databases and invisible to global academic metrics (Collyer et al., 2019, p183).

These linguistic inequalities and biases are a limitation in bibliometric analyses. Comprehensive, reliable data sources are essential for accurate bibliometric analyses and findings must be interpreted in light of this limitation. A regional and continental solution is needed to resolve and improve on coverage in order to have a more robust and clear picture of research activity in Africa.

That said, bibliometric analyses possess advantages and strengths that are very useful given that "publish or perish" has been a guiding philosophy for scientists that has shaped scientific culture and scientific citizenship. Publishing in journals anchors the peer-review process associated with current day science making. Publishing in peer reviewed journals is a foundational part of academic/research communication, making databases such as Web of Science and the publication data they collect credible and reliable. Journal databases over the years have become quite sophisticated offer incredibly vast amounts of in-depth data that can be mined for various analytical purposes. These purposes include ascertaining publication trends, mapping research activity and dynamics such as discipline evolution, collaboration patterns and mapping research funding sources. Bibliometric databases also provide an objective basis to make comparisons between countries, regions and thus a very useful resource for a regional bibliometric analysis such as this study sought to conduct (Hayatdavoudi et al., 2023; Pouris, 2010).

Despite the growth in bibliometric analyses globally, regional analyses of Southern Africa as a region are limited. This study aims to plug that gap by conducting a 23 year bibliometric analysis of SADC countries with four core objectives:

1. To evaluate and describe the publication trend in SADC over the period in review, 2000–2022
2. To identify the most prominent scientific fields and research areas across SADC

3. To examine the collaborative patterns of the outputs
4. To determine the most frequently cited research funders in the region's outputs

This bibliometric study used data drawn from the Web of Science (WoS) ALL DATABASES collection which offers the most comprehensive results and counts all document types in the collection and thus gives an overall picture of all the scientific outputs captured and indexed in the database. The WoS database covers comprehensively the most prestigious journals in the world in all fields of research endeavours and constitute a deep mine of publication data suitable for the objectives of this study.

Methodological process—in terms of process, the study began with a search of the WoS ALL DATABASES collection that began with extracting research publication outputs that were published between the years 2000–2022, the 23 year period in review for this study.

Thereafter, each country's outputs were analysed individually in order to identify publication trends, dynamics and patterns over time. The analysis further went on to analyse each country's outputs using the following filters that are available on WoS database. The following filters were applied:

– research areas (to map scientific disciplines)
– funding agencies (to identify funder profiles)
– Author affiliations (to trace patterns of co-authorships and collaborations).

The filters allowed the study to assess not only publication volumes but also thematic focus, collaboration networks and research funding dependencies – forming the basis for the empirical finding presented below in Section "Bibliometric Findings, Qualitative Discussion and Recommendations".

Bibliometric Findings, Qualitative Discussion and Recommendations

This section presents the key findings from the bibliometric analysis conducted on research outputs from the 15 SADC countries. The bibliometric analysis that follows was designed to address four main objectives which are to: ascertain the publication trends in the SADC region over the 23 year period from 2000 to 2022; identify the region's most prominent scientific fields; map collaborative patterns and investigate research funding sources. These results are interpreted alongside the socio-political and economic context discussed in Section "The Socio-Political Economy Undergirding Research and Knowledge Production in the SADC Region".

This section begins with an overview of total publication volumes by country (Table 2) and introduces the core research questions that guided the bibliometric analysis.

Table 2 Research publication outputs for the SADC region 2000 to 2022

Country	Country Total	% Share of Total	Articles	Meetings
Angola	2082	0,39	1 764	176
Botswana	9702	1,83	8 043	1 145
DR Congo	6655	1,26	5 514	563
Eswatini	1038	0,2	954	69
Lesotho	1070	0,2	908	105
Madagascar	6983	1,32	5 521	698
Malawi	12469	2,36	10 308	1 022
Mauritius	4671	0,88	3 692	871
Mozambique	6934	1,31	5 838	643
Namibia	5546	1,05	4 609	769
Seychelles	1127	0,21	975	68
South Africa	421176	79,55	306 448	46 249
Tanzania	26448	5	22 820	2 360
Zambia	9865	1,86	8093	1 091
Zimbabwe	13695	2,59	12 031	1 127
	529461	100%		

Country by Country Overview of Regional Research Output

The total research outputs of each SADC member state are summarised in Table 2 below, including their percentage share of regional output and disaggregation by document type (journal articles and conference proceedings).

Over the 23 year period, South Africa emerges as the dominant contributor, accounting for nearly 80% of the region's total outputs. This significant reflects South Africa's robust capacity enabled by research infrastructure, human resources and funding. In contrast, many other SADC countries contribute only marginally to the regional output. Tanzania and Zimbabwe follow as second and third but to levels way behind South Africa in terms of volume. Countries such as Seychelles, Lesotho and Eswatini have much lower outputs. Countries such as Eswatini, Lesotho and Seychelles each account for less than 0.5% revealing the uneven development of research ecosystems across the region.

Journal articles comprise the majority of the outputs, which is notable. Records of conference proceedings are also a notable form of research dissemination.

Appendix 1: Country Level Detail

To complement the regional assessment, Appendix 1 here: https://docs.google.com/document/d/1sGRfA0jnCmgWYPqfcKuYgOUTa1gNbk82Mm_BzjFccY0/edit?usp=sharing—provides granular, country by country output details and analysis. The analysis include publication trends overtime, dominant research areas, leading research funders and collaboration patterns in each country.

Publication Trends in the SADC Region over the Period in Review, 2000–2022

The bibliometric analysis reveals that SADC universities are the major role players contributing to the publication outputs and in each country only a few institutions

contribute to those outputs. This study found that outputs from SADC countries have been on a steady, upward trend despite the unevenness in research capacity and outputs across the region.

The SADC region's upward trend in scientific outputs echoes Africa's overall upward performance as continentally scientific outputs have been rising—from a world share 1.7% in 2010 to 3% in 2018 as found by study published in 2022 (Kahn, 2022a, b). The absolute number of articles by African authors in the Web of Science (WoS) rose from 1.4 percent in 2000 to 3.6 percent in 2020 (Boschoff et al., 2022). Similar findings are found in a bibliometric study by Ali and Elbadawy which found that South Africa was the top producer in Africa continentally followed by Egypt (Ali & Elbadawy, 2024).

South Africa's performance is due to various reasons that include factors discussed in Section "The Socio-Political Economy Undergirding Research and Knowledge Production in the SADC Region" of this paper, key of which is the fact that South Africa has the highest GERD ratio and thus higher investment and spend on R & D, This enables it to afford some of the best research infrastructure in the region. South Africa also hosts the oldest science granting council in the region. In addition in terms of recordkeeping of research activity, South Africa has certainly made more significant advances over the years in terms of recording its publication data and hosts a very sophisticated and established university and research system (Kahn & Oghenetega, 2021; Kahn et al., 2019).

South Africa also has the highest FTE ratio and hosts some of the best resourced research institutions, enabling it to attract talent across Africa broadly and international talent too. This ability to attract talent is corroborated by Cloete et al. whose study found that at "postgraduate level, ± 40% of its doctoral graduates hailed from elsewhere in Africa and 60% of her postdoctoral students were international" (Cloete et al., 2015).

To circumvent the research talent challenge, initiatives such as that by the Association of Commonwealth Universities (ACU) (ACU 2011:vii) emphasises the importance of grooming and equipping early-career researchers in Africa, and identifies the following five areas where support is needed to nurture this next generation in specific areas such as creating sufficient opportunities for peer learning, locally, regionally and internationally, through access to conferences, research collaborations. Other projects seeking to strengthen science systems in Africa to increase the number of doctoral candidates are doctoral support programmes by the German Academic Exchange Service (DAAD), and foundations such as that of Carnegie, Ford, and Bill & Melinda Gates (Beaudry & Mouton, 2018:26).

Affording early career researchers with further post-doctoral career development programs such as further training in grant writing, science communication and leadership training on master's and doctoral supervision. Some programmes seeking to redress this challenge in South Africa and across Africa through various initiatives such as the Partnership for Africa's Next Generation of Academics (PANGeA). PANGeA is "a network consisting of eight leading African universities focused on strengthening and advancing doctoral training and scholarship in the arts, humanities and social sciences on the continent, has launched a new training and skills development programme" (Stellenbosch University, n.d.). The Ford Foundation and other

higher education funders in Africa have invested heavily in increasing PhD graduates' improvement in Africa (Stellenbosch University, n.d.). In South Africa, the Department of Higher Education and Training (DHET), in 2015 launched the New Generation of Academics' Programme, or 'nGAP' (DHET, n.d.), to be implemented by all universities in South Africa (NACI, 2023).

Moreover, increasing the number of women in science can only strengthen science systems and African societies. Research shows that countries that create an enabling environment for women substantially improve their innovative capacity and competitiveness. Communities stand to gain from women's scientific contributions. This is equally true for the scientific research systems. "Gender equality will encourage new solutions and expand the scope of research. This should be considered a priority by all if the global community is serious about reaching the next set of development goals" (UNESCO, 2015:102).

The steady growth in research outputs across the regions, in spite of deep structural challenges shows the resilience of the SADC scientific community. However as already discussed this growth is uneven and closely tied to enabling conditions, key of which being research funding. Countries with more consistent investment in R & D, such as South Africa show higher research productivity. A thorough understanding of who funds research, to what extent, for what purposes is important for interpreting the volume and focus of scientific outputs. The next section maps the research funding landscape in the SADC region and explores implications.

Bibliometric Mapping of SADC Research Funding Sources – the Role of External Funders

The findings of this bibliometric analysis indicate limited local/national research funding across the region. To a greater degree external funders provide much needed research funding support to the SADC region, with the exception of Mauritius and South Africa as reflected in the barchart (Fig. 1).

An analysis of the top 20 cited funding agencies reveals 80% are international funders, with the exception of a South African funding agencies/institutions – the National Research Foundation of South Africa and the South African Medical Research Council. An analysis of the top 50 cited funders other South African funders that are visible in the data are the South African Research Chairs Initiative, the University of Cape Town, the University of KwaZulu Natal—the rest are international agencies, see detailed list in Appendix 2.

Appendix 2 is accessible here—https://docs.google.com/spreadsheets/d/14ykeZdlML74yPEWzU7OQjYEvYeB5QjAWX_ssEPHS12Q/edit?usp=sharing

The most acknowledged funders in the publications analysed by this study are largely external funders in international health research funders from the Global North. The most cited funders include the National Institutes of Health US; in the UK most cited funders include UKRI and the Wellcome Trust; the European Commission; the Bill and Melinda Gates Foundation; the World Health organisation and other international multilateral donors – Appendix 2 contains the comprehensive list of cited funders of research in SADC. Below is a bar chart reflecting the source of funding by country Fig. 2.

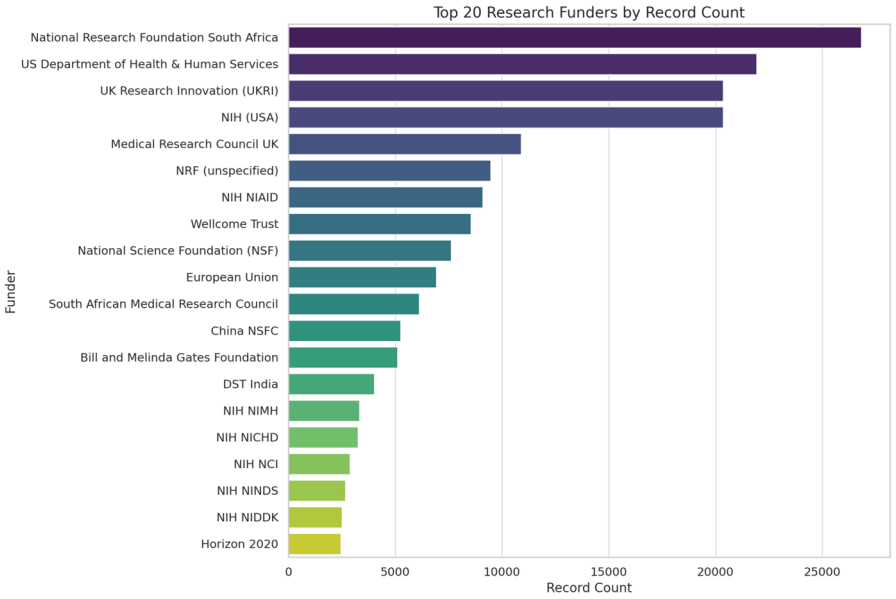

Fig. 1 Top 20 funding agencies by record count

The fact that local/African funders are largely absent from the Top 50 cited funders in the SADC data can also be explained by the low GERD ratios presented in Table 1 and discussed in earlier sections. The leading five countries in terms of gross expenditure on research and development (GERD) are South Africa, with research spending at 0.61% of GDP followed by Botswana at 0.54%, Tanzania at 0.51%, the DRC at 0.41%, and Mauritius at 0.35% of GDP allocated to research activities (UNESCO Science Report, 2021). These five countries still fall short of the 1% of GDP target set by the African Union (SADC, 2020). This is way below global averages like the 2.5% OECD average. This chronic deficiency and underfunding results in lower research productivity, weak research infrastructures and constraints the ability of research institutions to attract and retain talent in the region (Kraemer-Mbula et al., 2023; Langat, 2021).

SADC countries should aim to persuade their political authorities for the importance of research and development for economic development (Chagwiza et al., 2024). Studies indicate a reciprocal relationship between knowledge production and research funding. Investing in research and development (R&D) not only strongly correlates positively with the volume of research publications but economic growth as well (Hayatdavoudi et al., 2023; Arvanitis et al., 2022).

Given such low funding levels and the constrained economic contexts that most SADC countries find themselves, international research funding is playing a much needed role in research activities. In a bid to supplement research incomes, most universities and research countries have grant-seeking departments whose work is to identify and apply for grant opportunities from research donors to keep the knowledge production processes running. But this scenario is unsustainable (Langat, 2021; Maher et al., 2020; Oanda & Sall, 2016).

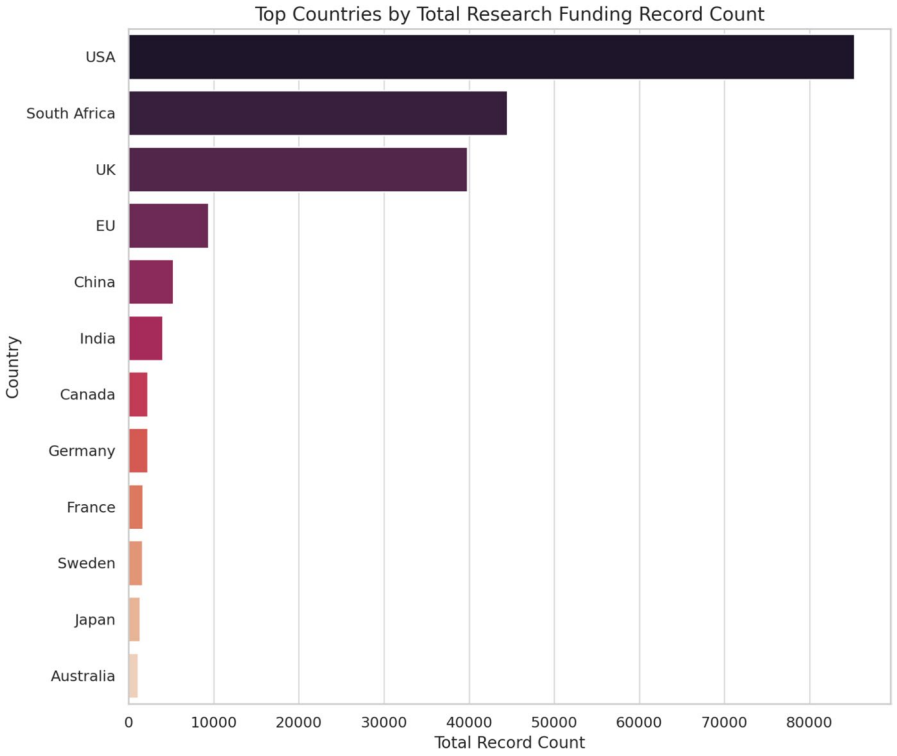

Fig. 2 Top funding countries by total funding record count

The over reliance on international funding for research efforts is practical in economically constrained environments but this over-reliance is not only unsustainable over time but a precarious position should that funding cease (Moja & Okunade, 2023). This is demonstrated by the recent funding cuts and funding freezes to Africa announced by the Trump administration in early 2025 which had adverse disruptive effects on health projects. As Mutapi argues, "The freeze of US aid to Africa in January 2025 is the latest in this trend. It's already having significant and wide-ranging impacts across the African continent. For example, vaccination campaigns for polio eradication and HIV/Aids treatment through the President's Emergency Plan for AIDS Relief (Pepfar) have been stopped. This puts millions of lives at risk. In South Africa alone, the cut of Pepfar's US$400 million a year to HIV programmes risks patients defaulting on treatment, infection rates going up and eventually a rise in deaths" (Mutapi, 2025).

The lack of sufficient domestic funding, puts SADC countries at the risk of external agendas and external research priorities which may not always be local priorities. The research funding priorities of any given funding agency are guided by what that agency considers and defines as pressing and important. Chu et al. found that often funders dictate the priority areas and caution that African countries risk repeating history and becoming victims of 'scientific colonialism' because 'he who pays the piper dictates the tune' and 'help is the sunny side of control' (Chu et al., 2014). Gastrow

similarly cautions that "Charity is patronising, charity involves unbalanced power relations, and charity often removes personal dignity and undermines self-reliance. What is important is how the contributions made to improve society happen, and they cannot take place in a charitable paradigm" (Gastrow, 2016). In a study of agenda setting in Kenyan health research. Lairumbi et al. found that "The agenda for research was determined more generally, and the actors involved, suggests that the considerable power of the global health agenda, often aimed at current crises, and the research financing tied to them, may inhibit the development of a more varied or context specific local agenda. The challenge for many African grantees of external research grants is whether the funders' priorities match the research and disease priorities of their own countries and environments" (Lairumbi et al., 2008).

When SADC countries fail to fund their own research and innovation efforts they miss a critical opportunity to better align research activities with country needs and priorities. The Trump-era funding cuts underscore the importance of self-reliance and the need for domestic funding for research and innovation.

The funding landscape reveals critical dependencies in SADC research systems. But herein is an opportunity for building greater resilience, self-determination and regional integration. A noteworthy example helping to build this resilience is the the Science Granting Councils initiative (SGCI). The SGCI was launched to address challenges faced by public research funding agencies in the sub-Saharan region. The initiative works to help establish local public research funding councils where they don't (SGCI, n.d.). Well-coordinated and resourced public research funding institutions can certainly help improve research priority setting and coordination to ensure that resources are allocated to priority research areas for a given country or region where they are needed the most. Control of research priority setting is critical if research efforts are to lead to desired societal impacts and meet local needs. Another example is the O.R. Tambo Africa Research Chairs Initiative (ORTARChI) whose mission is to "leverage existing continental frameworks and interventions geared towards institutional capacity strengthening; recruitment and retention of excellent researchers; and incentives to support research that contributes to socio-economic and transformative development" (SGCI, n.d.). The SGCI's ten (10) O.R. Tambo Africa Research Chairs are spread across seven (7) countries in Africa, namely; Botswana, Burkina Faso, Ghana, Mozambique, Tanzania, Uganda and Zambia. These research Chairs were selected for funding and are focused on research priorities identified by each host institution in alignment with AU Agenda 2063 and STISA 2024 (SGCI, n.d.).

Bibliometric Mapping of SADC's Main Research Areas

In terms of the major/top five (5) research areas, this analysis found that besides a few thematic differentials by country, broadly within the SADC outputs, environment sciences/ecology are the top research area (+99,000 publications). This is followed by infectious diseases (+72300 publications) and third public environmental occupational health (+60300). Fourth, science, technology related topics (+58,000) and fifth is chemistry (55726 publications) and close six is engineering (+55400 publication). See appendix 2 for a detailed breakdown of all the SADC research

areas. Social sciences and humanities are under-represented – psychology (43 523 publications), educational research (29237 publications), anthropology (10368 publications). Humanities fields like philosophy, history and literature are lower down the list.

An analysis of the top 50 research areas of the SADC (See Appendix 2) reveals the top clusters as follows in Fig. 3.

The research clusters were grouped by amalgamating publication counts of the top 50 research areas as follows:

- **Health & life sciences**—Biochemistry, Healthcare Sciences, Pharmacology, Immunology, Pediatrics, Pathology, Internal Medicine, Reproductive Biology, Nutrition, Physiology, Experimental Medicine, Parasitology, Toxicology, Neurology, Cardiology, Respiratory, Hematology, Virology, Obstetrics.
- **Environment & ecology**—Environmental Sciences, Public Health, Zoology, Plant Sciences, Biodiversity Conservation, Meteorology, Water Resources.
- **Social sciences & humanities**—Business & Economics, Psychology, Behavioural Sciences, Education, Sociology, Government & Law, Demography.
- **Engineering & technology**—Engineering, Physics, Materials Science, Energy & Fuels, Computer Science.
- **Energy & applied sciences**—Science & Technology (Other Topics), Chemistry.
- **General science & multidisciplinary**—Mathematics, Life Sciences (Other Topics).
- **Agriculture & food**—Agriculture, Food Science & Technology.

The dominance of health related research also shows the close relationship between the research thematic areas and the most cited funders who are largely global health research funders. The prevalence of health related research makes sense given that Africa accounts for 25% of the global disease burden and these include various infec-

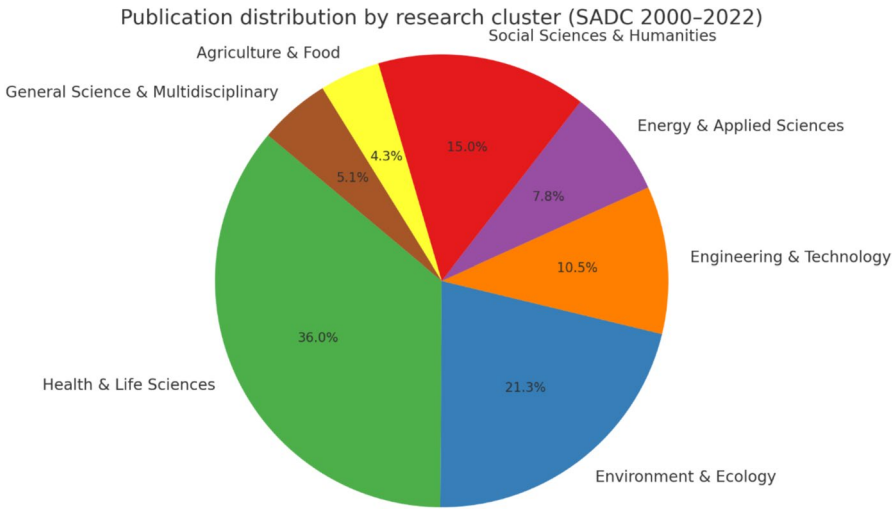

Fig. 3 SADC Publication distribution by research cluster (2000–2022)

tious diseases, heart disease, diarrheal diseases and HIV/AIDS are leading causes of death in Africa and low-income countries (Head et al., 2013:35; WHO Africa, 2014:10).

The World Health Organization (WHO) reported that communicable diseases pose the largest threat to human mortality and account for two thirds of the total disease burden in Africa. Communicable diseases of note are HIV/AIDS, tuberculosis (TB) and malaria, with the rest of the diseases being non-communicable diseases (NCDs) and injuries. The most significant non-communicable diseases include cardiovascular diseases, chronic respiratory diseases, cancer, sickle cell disease, mental and neurological disorders, road traffic injuries and other complex disease interactions (Beaudry & Mouton, 2018, WHO Africa, 2014:73–78). Malaria and HIV/AIDS are amongst the biggest disease burdens in Africa. In 2015, more than 730 000 malaria-related deaths were reported (WHO, 2017). The WHO reports that Africa is the most HIV/AIDS-affected region globally, accounting for two thirds of the global total of infections. An estimated 25.6 million people were living with HIV in 2016 (WHO, 2017, Cardoso et al., 2014). And yet, health is critical to the well-being of any nation and the economic productivity of any nation (Rotich & Onyancha, 2017:22). Access to healthcare services is key, and equally important is health research as we seek new vaccines, new technology to cure old and/or known diseases, as well as new ones as the diseases develop, and improve the health outcomes of a population (Paruk et al., 2014:468).

Unfortunately however, when compared with the rest of the world, despite Africa being the host of the disease burden, medical research initiating from the most disease-prone countries is significantly low. Studies such as the one by Chu et al. (2014:e1001612) revealed that sub-Saharan Africa (SSA) produces less than 1% of biomedical research publications. More in-depth studies and analyses are required to fully assess the impact of foreign research funding on grantee countries in Africa, to answer the question of whether externally funded grants are beneficial or more extractive and also to analyse if these funding instruments are aligned to local priorities.

The prominence of environmental/ecology research also makes sense given the acute challenges the SADC region is facing in terms of climate change, water/rainfall shortages. These factors have direct impacts on the agriculture sector which is the highest employer in SADC, biodiversity loss, ultimately, these challenges impact on food security (Kapuka and Hlasny, 2021; Falayi et al., 2021; Ziervogel, 2018).

The third research cluster is social science and humanities that make up 15% of the publications.

Strategic research areas with room for improvement—The SADC region's economic growth and prospects for increased job creation lie in manufacturing, value addition to its natural resources. To this end, there are some key research areas where the SADC region could pay more attention to, these are: engineering (ranks number 6 in the data publication analysed), materials science (publications rank 31), energy (publications rank 40), applied physics (rank 24), computer science (rank 22) and industrial biotechnology (publications rank 73). There is certainly room for improvement in these critical research areas in order to drive economic development, industrial growth and innovation. Inglesi-Lotz and Pouris argue that "Globally, countries with high innovation levels and improvements in technology have generally pro-

Table 3 Top collaborating countries for the SADC region

Country	1 st Collaborating Country	2nd Collaborating Country	3rd Collaborating Country	4th Collaborating Country	5th Collaborating Country
Angola	Portugal	USA	Brazil	Cuba	Spain
Botswana	USA	South Africa	England	India	Australia
DRC	Belgium	USA	France	England	Switzerland
Eswatini	South Africa	USA	England	Switzerland	Kenya
Lesotho	South Africa	USA	Switzerland	Zimbabwe	Malawi
Madagascar	USA	France	England	Germany	Switzerland
Malawi	USA	England	South Africa	UK	Kenya
Mauritius	England	South Africa	USA	India	France
Mozambique	USA	Spain	South Africa	England	Brazil
Namibia	South Africa	USA	England	Germany	Australia
Seychelles	USA	England	France	Switzerland	South Africa
South Africa	USA	England	Germany	Australia	France
Tanzania	USA	England	Kenya	South Africa	Germany
Zambia	USA	England	South Africa	Kenya	Uganda
Zimbabwe	South Africa	USA	England	Kenya	Uganda

duced more research publications in disciplines of technology than other types of science. That is to say, those countries that drive technology research globally tend to enjoy higher levels of economic growth, living standards and development" (Inglesi-Lotz & Pouris, 2018).

Bibliometric Mapping of SADC Research Collaboration Patterns

Research collaboration is a crucial element of research activities. Table 3 below reflects the following top 5 collaborating countries for each of the countries based on the bibliometric data analysed.

This study used co-authorship patterns as proxy (Kahn, 2018; Mouton & Beaudry, 2019, Hedt-Gauthier et al., 2019), and found that intra-SADC collaboration are weak. Amongst all the 15 countries, there are much more co-authorships with Global North partners—the US, UK, France, Germany and Switzerland than intra-regional partnerships.

The collaboration patterns analysed also reflect funding-based ties as well as the linguistic and historical colonial patterns, where for countries like Angola and Mozambique partner much more with Portugal. Similarly the DRC, Seychelles and Madagascar co-author much more with French and Belgian partners.

Within the SADC region South Africa is a key node and features as the main regional collaborating partner for the SADC countries. However, on the contrary, an in depth analysis of South Africa's own collaboration patterns with the rest of SADC revealed that South Africa collaborates much more with international partners than the rest of the region. Another bibliometric study that corroborates this finding, but used a different database/Scopus, was conducted by Heleta and Jithoo and the study found the same when they analysed South Africa's collaborative patterns between the years 2012–2021. Their study revealed "growth in research collaboration with

Brazil, Russia, India, China and Nigeria, South African universities continue to be largely Eurocentric and prioritise collaboration with the Global North while sidelining research collaboration with the African continent and Global South" (Heleta & Jithoo, 2023a, b). Other studies with similar findings, include a continental study by Pouris and Ho (2014) that analysed research collaboration patterns in Africa between the years 2007–2011. The study found that international co-authored publications grew from 52% in 2007 to 58% in 2011. Similarly, a study by Mouton and Blanckenberg (2018) for the period 2005–2016, found that African researchers and scientists collaborated chiefly with international/partners outside the African continent. A UNESCO study using WoS bibliometric data that analysed the period between 2008–2014 also looking at SADC collaborations found a similar picture (UNESCO, 2015:545).

In explaining collaboration patterns, Confraria et al. (2019) argue that international collaborations in Africa are more prominent for a number of reasons that include partnerships with international collaborators in-order to gain access to funding and to also access to research infrastructure that may not be available locally or on the continent. Thus international collaborations are a way to build research capacities. Mouton et al., similarly concur that because "Africa's research institutions largely depend on foreign funding for their research performance. This funding is often linked to a Northern-based principal investigator in the United States or Europe who by default is indicated as an international co-author of the publications emanating from the funded research" (Mouton & Beaudry, 2019). Other reasons for collaboration include common research interests, collaboration as a result of student-supervisor interactions, existing inter-institutional partnership agreements, and funding agency requirements (Maluleka et al., 2016; Owusu-Nimo & Boshoff, 2017; Beaudry et al., 2017).

The OR Tambo Africa Research Chairs Initiative is a good example of how to catalyse and support more intra-Africa research collaborations through joint research project. The Initiative seeks to build research capacity in specific research areas, facilitate knowledge exchange, and build research infrastructure development through these strengthened collaborations while addressing shared societal challenges. The research chairs are from seven (7) countries namely; Botswana, Burkina Faso, Ghana, Mozambique, Tanzania, Uganda to work on focused on research priorities aligned with AU Agenda 2063 and STISA 2024 continental frameworks (SGCI, n.d.). More initiatives of this nature at a regional and continental level will be valuable.

Data Gaps, Language and Indexing Barriers

This study also found data gaps, for example data related to GERD, BERD, and granular more detailed data about the number of FTE in the region. This limits and constrains efforts to evaluate the system adequately and make evidence based recommendations. In terms of language, due to the under-representation of non-English publications on WoS indexed publications, for countries like Angola, Comoros, the DR Congo, Seychelles and Madagascar whose languages are Portuguese and French, reflected much lower publication volumes. This results in diminished research visibility, regionally and globally (Aldirgiri, 2024; Artigas et al., 2022; Rakotondravony et al., 2023; Kahn, 2022a, b).

As discussed in Section "Bibliometric Methodology, Objectives, Data Source, Timeframe and Limitations", bibliometric data is limited and can only offer a partial picture of the research and research funding landscape as many authors and many publications don't cite and share their funding sources. However, outside of bibliometric data, there is a lack of an easily accessible bank of information on research funding in Africa i.e. who is providing the funding, which disciplines are funded, what are the types of funding offered, and the extent and effect of the funding, and this is problematic. The African Observatory of Science, Technology and Innovation (AOSTI) whose mission as a continental platform is to collect, analyse and make sense of information about science, technology and innovation in Africa could certainly add tracking science and innovation funding to their portfolio (AU, n.d.).

A more transparent research funding landscape would be useful for all science stakeholders including funding agencies in terms of planning how to allocate their budgets, how to support the region and leverage on the funding that is available for shared challenges, avoid duplication and inefficiencies. The African Union through its African Union Research Grants Programme is meant to disburse research grants, however, no information is readily available publicly about the grants and also very little academic research has been done to gauge the impact and scale of these grants, making this an area of future academic studies (AU, n.d.).

Conclusion and Recommendations

This paper had two main objectives: first, to present an in-depth analysis of the political economy and ecosystem for science within the SADC region, analysing the key factors that impact on performance; and second, to characterise research publication trends and traits over a 23 year period, 2000–2022.

The findings indicate a strong association between inputs such as qualified researchers, research funding and research output. Countries such as South Africa and Mauritius that are investing in their research ecosystems perform better. Conversely, chronic underfunding of R & D limits productivity and undermines research sovereignty. This study reinforces the importance of stable domestic funding, robust research infrastructure for research to flourish. Domestic funding for research is currently limited and represents a priority for strengthening research sovereignty. The region's dependence on international funding is severe and leaves its research systems vulnerable to external conditions and priorities.

Without increased domestic funding investments, African science systems are likely to remain dangerously exposed and vulnerable to the volatility of global geopolitical shifts and donor agendas. The 2025 suspension of US funding to Africa under the Trump administration provides a cautionary example. Within weeks critical health programmes were disrupted, highlighting the fragility and vulnerability of systems reliant on external support. If and when international priorities shift, entire research agendas and health programmes are at risk of collapse. This incident illustrates the importance of developing local funding mechanisms that ensure sustainability and sovereignty.

Talent development and improving gender equity in science should also be a priority. Strengthening doctoral programmes, supporting early-career researchers and promoting women in STEM will be critical to address the region's talent pipeline challenges.

The bibliometric analysis shows that, although research publications have been increasing, this growth is uneven, minimal in some countries and largely dominated by South African publications. Health related research outputs lead in the outputs followed by agriculture, environment and ecology research. There are some key research areas where the SADC region could pay more attention. These are engineering; materials science, energy, applied physics, computer science and industrial biotechnology. These research areas are essential to support value addition, industrial growth and the region's innovation agenda.

In terms of partnerships and research collaboration, international co-authorships are more prominent and intra-regional partnerships are limited. Factors such as historical colonial ties, shared language shape and influence research collaborations. South Africa is an anchor, and the key collaborator for the rest of the region. However, South Africa's own regional and intra-Africa collaborations are low. While international partnerships are valuable, SADC countries are missing out on a vital and strategic opportunity to collaborate and build regional integration through science. Intra-Africa collaborations could greatly contribute to leveraging resources, co-creation, and shared problem solving and supporting the epistemological decolonisation of African knowledge production.

Despite constraints, the SADC's research systems exhibit resilience and characterised by untapped potential – an ecosystem that, with the appropriate support could evolve into a knowledge economy rooted in African realities and aspirations. The Science, Technology and Innovation Strategy for Africa 2024 (STISA–2024), provides a clear framework and compelling vision. It firmly positions the importance of research, technology and innovation in developing Africa. In building towards the STISA vision, progress has been made: fourteen of SADC's fifteen member states now have STI policies in place. A majority of the SADC states have also taken positive steps by creating dedicated government departments responsible for STI. However, implementation of these frameworks and plans is weak and the political economy of science in the region is currently a challenging one. This is due to weak research infrastructure, limited staffing—exacerbated by the exclusion of women from science- and critically low funding levels. To date, no SADC country has met the African Union's target of investing 1% of GDP into research and development. The over-reliance on international funding undermines research sovereignty. Strengthening research funding as a political, economic and developmental priority would be critical for SADC governments to adequately finance their research agendas.

The sustainable future of African science depends on building resilient African research systems and institutions that serve local needs, are aligned to local research priorities and financed by African resources. Based on the findings, three actionable policy recommendations emerge. First, governments in the SADC region should prioritise increased and sustained domestic funding for research, which requires moving toward the African Union target of 1% of GDP to reduce over-reliance on international donors. Second, investment in talent pipelines, particularly doctoral training,

early career-researcher support and women's participation in STEM. It is essential and advantageous to build a strong and inclusive talent base. Third, fostering stronger intra-regional collaboration, alongside international research partnerships. This can enhance resource sharing, support co-creation and strengthen the region's collective research sovereignty. These actions would enable the region to move beyond vulnerability and build a robust knowledge economy.

Author Contributions **Author 1** the Corresponding author, Conceptualization of the research question, research design and methodology, data gathering and analysis, writing the manuscript, responding to reviewer comments, and addressing revisions.
Author 2 Contributed to the conceptualization of the research topic, provided critical input on methodology, offered guidance throughout the study, helped resolve challenges during data collection, reviewed and provided feedback on manuscript drafts, and assisted in revising the manuscript in response to peer review.

Funding Open access funding provided by University of Pretoria.

Data Availability Data is available to the corresponding author upon reasonable request.

Declarations

Conflict of interests The author declares no conflict of interest.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

ACU (Association of Commonwealth Universities). (2011). *Foundations for the future: Supporting the early careers of African researchers*. Paper commissioned by the British Academy as part of the Nairobi Process. Britain: The British Academy.

AFDB (African Development Bank). (2015). *African economic outlook: Regional development for spatial inclusion in Africa.* Abijan, Cote d'Ivoire.

African Union. (n.d.). *Agenda 2063: The Africa we want*. https://au.int/en/agenda2063

Aldirdiri, O. (2024). Navigating the digital divide: Challenges and opportunities in research publishing for African scholars. *European Review*. https://doi.org/10.1017/S1062798724000073

Ali, M., & Elbadawy, A. (2024). Scientific research productivity in Africa: Trends and patterns. *Journal of Informetrics*.

Artigas, W., Gungula, E. W., & Laakso, M. (2022). Open access in Angola: A survey among higher education institutions. *Scientometrics, 127*, 3977–3993. https://doi.org/10.1007/s11192-022-04410-w

Arvanitis, R., Mouton, J., & Néron, A. (2022). Funding research in Africa: Landscapes of re-institutionalisation. *Science, Technology & Society, 27*(3), 351–367. https://doi.org/10.1177/09717218221078235. Original work published 2022.

AU (African Union). (2014). *On the wings of innovation: The science, technology and innovation strategy for Africa 2024 (STISA 2024).* Retrieved from http://www.nepad.org/content/science-technology-innovation-strategy-africa-stisa-south-africa

Beaudry, C., & Mouton, J. (2018). *Young scientists in Africa: Factors influencing research performance and career development.* Stellenbosch: Centre for Research on Evaluation Science and Technology, Stellenbosch University.

Beaudry, C., Mouton, J., Blanckenberg, J., Huet, P., Prozesky, H., St-Pierre, C., & Swart, C. (2017). *Young scientists in Africa: Factors influencing research performance and career development: preliminary results*. Technical Report.

Boshoff, N., Pienaar, H., & De Wet, K. (2022). Research performance of Africa: A bibliometric analysis. *Scientometrics, 127*(2), 1231–1250. https://doi.org/10.1007/s11192-021-04200-0

Bunting, I., Cloete, N., & Van Schalkwyk, F. (2014). *An empirical overview of eight flagship universities in Africa: 2001–2011*. Centre for Higher Education Transformation.

Cardoso, L., Breugelmans, G., Manville, C., Chataway, J., Cochrane, G., Snodgrass, J., Chataway, M., & Murali, N. (2014). *Africa mapping: Current state of health research on poverty related and neglected diseases in sub-Saharan Africa*. EDCTP.

Castells, M. (2000). *The rise of the network society* (2nd ed., Vol. 1). Blackwell Publishers.

Chagwiza, C., Owusu-Sekyere, E., & Kapfudzaruwa, F. (2024). The effect of governance on the relationship between research and development expenditure and economic growth in South Africa. *Economies, 12*(12), 324. https://doi.org/10.3390/economies12120324

Chu, K. M., Jayaraman, S., Kyamanywa, P. & Ntakiyiruta, G. (2014). *Building research capacity in Africa: Equity and global health collaborations.* PLOS Medicine, *11*(3). https://doi.org/10.1371/journal.pmed.1001612

Cloete, N., Maassen, P., & Bailey, T. (2015). *Knowledge production and contradictory functions in African higher education*. African Minds.

Collyer, F., Connell, R., Maia, J., & Morrell, R. (2019). *Knowledge and global power: Making new sciences in the South*. Wits University Press.

Confraria, H., Blackenberg, J., & Swart, C. (2019). *Which factors influence international research collaboration in Africa?* Springer.

Costas, R., Van Leeuwen, T., & Bordons, M. (2010). A bibliometric classificatory approach for the study and assessment of research performance at the individual level: The effects of age on productivity and impact. *Journal of the American society for information science and technology, 61*(8), 1564–1581.

Falayi, M., Gambiza, J., & Schoon, M. (2021). A scoping review of environmental governance challenges in Southern Africa from 2010 to 2020. *Environmental Conservation*, *48*(4). https://doi.org/10.1017/S0376892921000333

Fon Tata, E., et al. (2023). Decolonizing African science: Efforts, challenges, and future directions. *International Journal of Science and Research Archive, 10*(1), 823–833.

Gaillard, J., & Mouton, J. (2022). The state of science, technology and innovation in Africa: Trends, progress and limitations. *Science, Technology and Society*, *27*(3). https://doi.org/10.1177/09717218221078548

Gastrow, S. (2016). *Student protests and third stream income.* Daily Maverick, 10 October. Retrieved from https://www.dailymaverick.co.za/opinionista/2016-10-10-student-protests-and-third-stream-income/#.WhWCrkqWbIU

Hayatdavoudi, J., Kaltenbrunner, W., & Costas, R. (2023). Science and research landscapes across D-8 organization member countries from a historical perspective: The policy context and collective agendas. *Quantitative Science Studies*. https://doi.org/10.1162/qss_a_00249

Head, M. G., Fitchett, J. R., Cooke, M. K., Wurie, F. B., Atun, R., & Hayward, A. C. (2013). Systematic analysis of funding awarded for infectious disease research to institutions in sub-Saharan Africa, 1997–2010. *BMJ Open, 3*(12), e003105. https://doi.org/10.1136/bmjopen-2013-003105

Hedt-Gauthier, B. L., Jeufack, H. M., & Neufeld, N. H. (2019). Stuck in the middle: A systematic review of authorship in collaborative health research in Africa, 2014–2016. *BMJ Global Health, 4*, e001853. https://doi.org/10.1136/bmjgh-2019-001853

Heleta, S., & Jithoo, D. (2023a). International research collaboration between South Africa and rest of the world: An analysis of 2012–2021 trends. *Transformation in Higher Education, 8*(0), a246. https://doi.org/10.4102/thev8i0.246

Heleta, S., & Jithoo, D. (2023b). Differing priorities: International research collaboration trends of South African universities, 2012–2021. *Perspectives in Education, 41*(4), 252–274. https://doi.org/10.38140/pie.v41i4.7471

Inglesi-Lotz, R., & Pouris, A. (2018). Does South African research output promote innovation?. *South African Journal of Science*, *114*(9/10). https://doi.org/10.17159/sajs.2018/a0286

International Monetary Fund. (2015). Macroeconomic developments in low-income developing countries 2015. *International Monetary Fund*. https://www.imf.org

Kahn, M. J. (2018). Co-authorship as a proxy for collaboration: A cautionary tale. *Science and Public Policy, 45*(1), 117–123. https://doi.org/10.1093/scipol/scx052

Kahn, M. J. (2022a). An exploratory study of the social contract of research and innovation in Africa. *Frontiers in Research Metrics and Analytics, 7*, 849263. https://doi.org/10.3389/frma.2022.849263

Kahn, M. (2022b). The status of science, technology and innovation in Africa. *Science, Technology & Society, 27*(3), 327–350.

Kahn, M., & Oghenetega, J. (2021). Origins and destinations known: A tracer study of international African doctoral graduates from South African universities. *Industry and Higher Education*. https://doi.org/10.1177/0950422221989645

Kahn, M., Gamedze, T., & Oghenetega, J. (2019). Mobility of sub-Saharan Africa doctoral graduates of South African universities: A tracer study. *International Journal for Educational Development, 68*, 6–14.

Kapuka, A., & Hlásny, T. (2021). Climate change impacts on ecosystems and adaptation options in nine countries in southern Africa: What do we know? *Ecosphere, 12*(12), e03860. https://doi.org/10.1002/ecs2.3860

Kiwelu, J., Gatiti, P., & Okure, A. A. (2023). A bibliometric analysis of biomedical research productivity in Africa South of Sahara 2010- 2022. *Libraries*. http://ecommons.aku.edu/libraries/78

Kraemer-Mbula, E., Hanlin, R., Byrne, R., Daniels, C., & Kingiri, A. (Eds.). (2023). *Transformative innovation in times of change: Lessons for Africa from the 2020 global pandemic*. African Minds. https://www.africanminds.co.za/wp-content/uploads/2024/02/Transformative_innovation_COVID_WEB.pdf

Lairumbi, G.M., Molyneux, S., Snow, R.W., Marsh, K., Peshu, N. & English, M. (2008). *Promoting the social value of research in Kenya: Examining the practical aspects of collaborative partnerships using an ethical framework*. Elsevier Social Science.

Langat, A. (2021). *Is donor dependency stifling African health research? Devex*. https://www.devex.com/news/is-donor-dependency-stifling-african-health-research-100104

Leonard, A., Hamutumwa, N., & Mabuku, M. (2022). A bibliometric analysis of how research collaboration influences Namibia's research productivity and impact. *SN Social Sciences, 2*, 225. https://doi.org/10.1007/s43545-022-00528-z

Lundvall, B. -Å. (1992). *National systems of innovation: Towards a theory of innovation and interactive learning*. Pinter Publishers.

Maher, D., Aseffa, A., Kay, S., et al. (2020). External funding to strengthen capacity for research in low-income and middle-income countries: Exigence, excellence and equity. *BMJ Global Health*. https://doi.org/10.1136/bmjgh-2019-002212

Maluleka, J. R., Onyancha, O. B., & Ajiferuke, I. (2016). Mapping collaboration patterns of South African research output. *South African Journal of Science, 112*(7/8), 1–9.

Mohamedbhai, G. (2024, April 5). *Higher education in Africa: Pathways to relevance and impact*. University World News. https://www.universityworldnews.com/post.php?story=20240403123756208

Moja, T., & Okunade, S. K. (2023). *African science granting councils: Towards sustainable development in Africa*. African Minds.

Mouton, J., & Beaudry, C. (2019). *The Next Generation of Scientists in Africa.* African Minds. Project MUSE. muse.jhu.edu/book/63750

Mutapi, F. (2025). *Africa relies too heavily on foreign aid for health – 4 ways to fix this*. The Conversation. https://theconversation.com/africa-relies-too-heavily-on-foreign-aid-for-health-4-ways-to-fix-this-249886

NACI (National Advisory Council on Innovation). (2017a). A *Review of the White Paper on Science and Technology*. The NACI Secretariat.

NACI (National Advisory Council on Innovation). (2017b). *The 2016 South African science, technology and innovation indicators.* The NACI Secretariat.

National Advisory Council on Innovation. (2023). *South African science, technology and innovation indicators report*. NACI. https://www.naci.org.za

Ndlovu-Gatsheni, S. J. (2018). The dynamics of epistemological decolonisation in the 21st century: Towards epistemic freedom. *Strategic Review for Southern Africa, 40*(1), 16–45. https://africasocialwork.net/wp-content/uploads/2022/12/Ndlovu-Gatsheni-2018-THE-DYNAMICS-OF-EPISTEMOLOGICAL-DECOLONISATION-IN-THE-21ST-CENTURY-TOWARDS-EPISTEMIC-FREEDOM.pdf

New Partnership for Africa's Development (NEPAD). (n.d.). *Science, technology and innovation initiatives in Africa*. https://nepad.org

Oanda, I. & Sall, E. (2016). From peril to promise: Repositioning higher education for the reconstruction of Africa's future. *International Journal of African Higher education*. Retrieved from https://ejournals.bc.edu/ojs/index.php/ijahe/article/view/9637

OECD (Organisation for Economic Co-operation and Development). 2016. *G20 innovation report*. Paris France. OECD.

Organisation for Economic Co-operation and Development. (2015). Frascati manual 2015: Guidelines for collecting and reporting data on research and experimental development. OECD Publishing. https://doi.org/10.1787/9789264239012-en

Owusu-Nimo, F., & Boshoff, N. (2017). Research collaboration in Ghana: Patterns, motives and roles. *Scientometrics, 110*(3), 1099–1121. https://doi.org/10.1007/s11192-016-2221-x

Paruk, F., Blackburn, J. M., Friedman, I. B., & Mayosi, B. M. (2014). National expenditure on health research in South Africa: What is the benchmark? *South African Medical Journal*. https://doi.org/10.7196/SAMJ.6578

Pouris, A. (2010). A scientometric assessment of the Southern Africa Development Community: Science in the tip of Africa. *Scientometrics, 85*, 145–154. https://doi.org/10.1007/s11192-010-0260-2

Pouris, A. (2015). An assessment of South Africa's research journals: Impact factors, eigen factors and structure of editorial boards. *South African Journal of Science, 111*(3/4), 1–8.

Pouris, A., & Ho, Y. (2014). Research emphasis and collaboration in Africa. *Scientometrics, 98*(3), 2169–2184.

Pouris, A., & Pouris, A. (2011). Scientometrics of a pandemic: HIV/AIDS research in South Africa and the world. *Scientometrics, 86*(2), 541–552.

Rakotondravony, N., Dhawka, P., & Bancilhon, M. (2023). *Beyond English: Centering multilingualism in data visualization* [Preprint]. arXiv. https://arxiv.org/abs/2309.06659

Rotich, D. C., & Onyancha, O. B. (2017). Trends and patterns of medical and health research at Moi University, Kenya, between 2002 and 2014: An informetrics study. South African *Journal of Libraries and Information Science*. http://sajlis.journals.ac.za. https://doi.org/10.7553/82-2-1626

SADC - Southern African Development Community. (2020). *Annual report 2019/2020*. SADC Secretariat. https://www.sadc.int

Science Granting Councils Initiative. (n.d.). *Strengthening research and innovation systems in Africa*. https://sgciafrica.org

Sillitoe, P. (2006). Indigenous knowledge in development: *Anthropology in Action, 13*(3), 1–12. https://doi.org/10.3167/aia.2006.130302

SU (Stellenbosch University). (n.d.). PANGeA-Ed to bolster academic research capacity in Africa. Retrieved from https://www0.sun.ac.za/international/news/pangea-ed-to-bolster-academic-research-capacity-in-africa.html

Tijssen, R., & Kraemer-Mbula, E. (2018). Research excellence in Africa: Policies, perceptions, and performance. *Science and Public Policy, 45*(3), 392–403.

UNESCO (United Nations Educational, Scientific and Cultural Organization). (2015). *UNESCO science report: Towards 2030.* Paris.

UNESCO. (2021). *UNESCO science report: The race against time for smarter development*. UN.

Wangui, G. (2024). Impact of colonial policies on indigenous education systems in Africa. *European Journal of Historical Research, 3*(2), 32–45.

Whitworth, A.G., Kokwaro, G., Kinyanjui, S., Snewin, V.A., Tanner, M., Walport, M. & Sewankambo, N. (2008). *Strengthening capacity for health research in Africa*. The Lancet.
WHO (World Health Organization). (2014). *The African regional health report 2014*. WHO.
WHO (World Health Organization). (2017). HIV/AIDS: *Key facts.* Retrieved from http://www.who.int/mediacentre/factsheets/fs360/en/
Wilmot, K., Iqani, M., & Madondo, N. (2023). Science and language, knowledge and power. *South African Journal of Science*. https://doi.org/10.17159/sajs.2023/16909
World Data. (n.d.). *SADC: South Africa and the Southern African development community*. Retrieved April 17, 2025, from https://www.worlddata.info/trade-agreements/sadc-southafrica.php
Working Group. (2016). *White paper: Measuring research output through bibliometrics*. University of Waterloo.
Ziervogel, G. (2018). Climate adaptation in South Africa: A case study on the complexities of urban governance. *Wires Climate Change, 9*(5), e567. https://doi.org/10.1002/wcc.567

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.