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Institutionalizing foresight in science, technology, and innovation in sub-Saharan Africa

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Abstract

Motivation: Foresight is increasingly being institutionalized and used in science, technology and innovation (STI) policy processes around the world. Foresight is a toolbox to help decision-makers generate intelligence about future scientific and technological advances and to frame long-term STI policy goals and rationales. Foresight can be used to inform policy to steer research and innovation (R&I) towards attaining sustainable development goals. Yet, foresight is not institutionalized and used in sub-Saharan Africa (SSA) at a time when many governments are formulating new STI policies and some of their science granting councils (SGCs) are setting R&I priorities.

Purpose: This exploratory study is about challenges and opportunities of institutionalizing STI foresight in SSA. It identifies ways of institutionalizing and using STI foresight.

Methods and approach: A literature review, bibliometric analysis, interviews, an online survey, and focus group discussions were conducted to identify challenges to, and lessons for, institutionalizing STI foresight in SSA. The literature identified good practices for institutionalizing STI foresight in selected developed countries, to draw lessons for SSA.

Findings: While academic research on STI foresight and related topics is increasing, there is very limited foresight practice in STI policy processes in SSA. This is mainly owing to low awareness of STI foresight, weak technical capacity, and generally a lack of foresight culture in STI policy-making in the region.

Policy implications: Building capacity within governments and establishing a community of practice in STI foresight may help improve the quality and effectiveness of STI policy in SSA. It may enable institutions such as science granting councils (SGCs) to make informed funding decisions, targeting scarce resources at priority research and innovation. Overall, building STI foresight literacy and skills, as well as establishing designated offices for STI foresight, supported by the knowledge to select and adapt foresight tools, will result in improved STI policy-making in SSA.

KEYWORDS
capacity building, foresight, policy-making, science, science granting councils, sub-Saharan Africa, technology and innovation

1 | INTRODUCTION

Foresight is about intelligence into and for the future (Panizzon & Barcellos, 2019). It can be used in many sectors and policy domains to inform decisions and plans. In science, technology, and innovation (STI) policy and research planning, foresight has become one of the main toolboxes (Pietrobelli & Puppato, 2015). There is a relatively large corpus of literature on "technology foresight," and indeed an increasing focus on STI foresight. A review of recent (2020–2022) selected articles in the leading journal *Futures* shows that the scope of technology foresight studies has been expanding to cover research on science and innovation (Saritas et al., 2022). In fact, developments in science and technology are shaping the focus and scope of foresight studies. Additionally, advances in data analytics are expanding the scope and possibilities of STI foresight studies and practices. Paradoxically, these advances are disruptive and create uncertainties, although they can be effectively managed by investing in building STI foresight capabilities.

Foresight in STI is about "strategic intelligence" and "sense-making" to identify and imagine possible futures in steering investments in STI to achieve sustainable development aspirations—such as those articulated in Agenda 2063 of the African Union (AU) and the United Nations Sustainable Development Goals (SDGs). It is also about intelligence into the future of STI and how STI will shape human futures. Martin (1995) provides a rich analysis of the benefits of technology foresight and why it should be institutionalized.

Many developed countries, and an increasing number of developing ones in Latin America and Asia, have institutionalized foresight as part of national STI policy-making. In sub-Saharan Africa (SSA), STI foresight is still in its infancy. No country in SSA has properly conceptualized or is actively applying foresight in STI policy processes. However, there have been some STI foresight activities in some countries, notably Botswana and South Africa, and at a continental level under the aegis of the African Union (AU). Some countries (notably Namibia, Ghana, Mozambique, and Seychelles) have applied some foresight methods—particularly SWOT (strengths, weaknesses, opportunities, and threats) analysis and horizon scanning—albeit in an ad hoc fashion, in their national STI policy review and revision efforts.

Demand for STI foresight is likely to grow in SSA for at least three reasons. First, SSA countries are putting increasing emphasis on the role of STI in sustainable development. This is reflected in the types of national STI policy frameworks that many countries in the region are adopting. Most modern STI policy frameworks being developed and adopted by SSA countries have long-term visions and anticipatory policy measures aligned with national development visions and the SDGs. This is a departure from STI policy regimes of the 1990s and early 2000s that were framed around short-term economistic rationales of increasing national economic competitiveness.

Second, SSA countries are exposed to a large and growing pool of scientific knowledge and technologies. Thus, it is critical for them to adopt and deploy specific tools and approaches for making wise technology choices, prioritizing research and innovation (R&I) and anticipating future technological advances. Rapid growth in scientific knowledge and technological innovations make it critical for SSA countries to take a long-term anticipatory planning approach for R&I. In this sense, STI foresight is increasingly being recognized as a vital 'methodological toolbox' for guiding the choice of specific R&D priorities and specific technologies to invest in.

Third, STI foresight is one of the "toolboxes" or techniques for effective governance of a country's national system of innovation (NSI). If it is organized as a participatory multi-stakeholder process, foresight can help to strengthen institutional linkages, enhancing policy coherence, and stimulate better articulation of actors in the NSI. Overall, STI foresight can be used by countries in SSA aspire to strengthen their NSIs, one of the common STI policy goals in the region.

For the above three reasons, SSA countries need to institutionalize STI foresight. The challenge is that they have limited capacity to design and use STI foresight. Yet, such capacity is more critical and urgently required during times of socioeconomic and ecological crises (and uncertainty) in an epoch of scientific and technological abundance. It is at times like these when governments, private sector, and even civil society organizations are

expected to make anticipatory decisions on how best to harness and apply new and emerging technologies to address complex multiple crises and steer the transition to sustainability.

This exploratory study is about challenges to and opportunities for institutionalizing STI foresight in the SSA region. It is an exploratory study in the sense that it draws mainly on a review of the literature and a rapid assessment of trends in STI foresight efforts of countries participating in the Science Granting Councils Initiative (SGCI). A more detailed systematic assessment of SSA countries' STI foresight capacity needs is needed. Drawing lessons from experiences of developed countries' efforts, the study suggests ways and means of institutionalizing STI foresight in SSA. It identifies STI foresight capacity needs or barriers to institutionalizing foresight for STI policy in the region.

Section 2 of the study provides an overview of the evolution, characteristics, and utility of STI foresight. Drawing from the literature, this section provides illustrative cases of how different developed countries have institutionalized STI foresight. The aim is to identify key lessons for institutionalizing STI foresight in SSA countries. Section 3 then considers the context in SSA and describes a methodological approach to assessing the current situation of STI foresight in SSA, with Section 4 outlining findings from this study, including a bibliometric analysis and empirical data on countries' experiences and indicative capacity needs in STI foresight. Section 5 outlines recommendations on how best to institutionalize STI foresight in SSA countries in general and within SGCs in particular. It proposes a generic STI foresight framework that takes into account unique conditions of SGCs in SSA countries with limited organizational capacities and budgets for STI.

2 | LITERATURE REVIEW

2.1 | Evolution of STI foresight

Foresight in STI has its origins in the 1940s during the Second World War, when systematic technology forecasting was used by military agencies in the USA and Europe. It has evolved over the past eight or so decades. Below is a summary of the evolution of STI foresight based on Miles et al. (2017).

1940s: Systematic technological forecasting emerged around the Second World War. Technological progress was understood as the accumulation of knowledge, contributed by many players, rather than from ad hoc and unpredictable insights from individual geniuses.

1950s–1960s: Tools and techniques were developed subsequently for technology forecasting in the context of military and megaprojects such as the US space programme. These were clustered as "futures studies."

1970s: Japan adopted and institutionalized analysis of STI opportunities, using "technology forecasting."

1980s–1990s: Several European countries and Canada realized that they were technologically lagging behind the US and Japan and started to develop ambitious technology forecasting programmes. It is during this period that the concepts "technology foresight" and "STI foresight" started to gain currency, replacing "technology forecasting."

2000s: International organizations such as the European Union (EU), Asia-Pacific Economic Cooperation (APEC), and United Nations Industrial Development Organization (UNIDO) started programmes for

technology foresight in different parts of the world. The EU supported new members from Central and Eastern Europe in the use of foresight to develop their national STI policies.

Popper (2018), Saritas and Anim (2018) and Andersen and Andersen (2012) discuss the following five generations of STI foresight.

- First generation (dynamics of technology, science push model)—science foresight, with a focus on natural sciences and engineering disciplines.
- Second generation (technology and markets, demand-pull model)—technology foresight, characterized by the recognition that successful transfer of technology should be informed by demand-side considerations or market needs.
- Third generation (integrating social dimensions to the technology and markets considerations, a couplings model)—toward a systems approach to STI foresight, characterized by a broadening of the demand-pull (technology and market perspective) by inclusion of a wider range of actors and social inclusion issues.
- Fourth generation (distributed role in the STI system, integrated model)—configured to engage and co-ordinate more diverse types of organizations and stakeholders in conducting foresight.
- Fifth generation (combined with other strategic forums, systems model)—covers a diversity of foresight levels, locations, dimensions, methods, design, and rationales, often at national level, and is concerned with the integration of structures or actors within the NSI and focuses on STI policy including broader social and economic issues.

Overall, STI foresight has evolved from a narrow focus on technology foresight (TF) to cover broader STI policy and NSI considerations. Modern STI foresight is characterized by a long-term orientation (vision); use of up-to-date tools and techniques (augmented intelligence); involvement of a broad base of expertise and stakeholders (inclusive co-thinking) and trans-disciplinarity. Overall, STI foresight has become sophisticated, requiring specialized inter-organizational capacities.

2.2 | Key features of STI foresight

There is a relatively rich body of studies on foresight methods. For example, Miles et al. (2016) comprehensively discuss foresight methodology and organization of foresight in general. They propose that foresight should be organized as a sequenced process starting with an initiation phase that includes a scoping exercise, recruitment of participants, and framing of issues. The initiation phase needs to be well managed, ensuring that potential participants receive adequate information and that the right mix of expertise is recruited for the foresight exercise. The main implementation phase would include organizing panels, brainstorming, and mind mapping. Popper (2009) offers a rich analysis of how to manage the implementation of foresight in a non-linear way involving the following steps: scoping of the issues (pre-foresight), mobilizing participants (recruitment), anticipating what may happen (scenario generation), recommending interventions (action and policy), and transforming the environment (renewal).

Commonly deployed foresight methods are SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, backcasting (working backward from a preferred scenario/vision to identify what measures or actions are required to achieve the end goal (Timilsina et al., 2020)), benchmarking, environmental or horizon scanning, expert panels, trend extrapolation, Delphi (procedure of asking a panel of experts for their opinion on a relevant issue, summarizing and presenting their collective responses and repeating this process for a certain number of rounds (Shang, 2023)), brainstorming, scenario planning, gap analysis, causal layered analysis (CLA) (a technique that allows for deconstruction of complex social issues (Breen et al., 2016)), emergent trends, disruptors, and wild cards and weak signals. The choice and combination of these methods should be guided by various factors including a country's organizational capacities, purpose, or aim in the use of foresight.

2.3 | Utility of STI foresight

Martin (1995) emphasized the role of foresight in informing governments to "identify the most promising research areas and the emerging technologies on which to concentrate resources and, hence, derive the fullest socioeconomic benefits." "STI for the future" focuses on mapping and evaluating specific STI pathways or roadmaps to determine their directionality and anticipated impact and/or alignment with future (sustainable development) goals (Ciarli, 2022). STI foresight can be conducted by or for government (public sector) and/or by or for firms (private industry). It can be conducted at global, regional, national, local, and firm levels, and can be designed to focus on a particular sector, a particular technology and development issue or challenge.

The utility of STI foresight for government (in the public sector) is STI policy-making and implementation (including STI policy monitoring and evaluation). The main uses and objectives of STI foresight are:

a. Informing STI policy-making: foresight can be used to inform the agenda-setting stage or first step in STI policy design, helping to frame STI policy vision, mission, and goals. It can be a vital process of gathering intelligence on possible future costs and benefits of specific STI policy interventions.
b. Stimulating interactions and learning within the NSI: foresight can help to build networks that bring together stakeholders from different sectors and institutions involved with various aspects of STI. Thus, it can be used to strengthen institutional linkages and foster information exchange key to the dynamic functioning of the NSI.
c. Developing capacity for STI policy: foresight can be designed and implemented to enhance the capacities of stakeholders (and organizations) to effectively participate in STI policy-making processes.

According to the United Nations Development Programme (UNDP GCPSE, 2018), effective general foresight exercises for development policy and planning are useful for:

a. *Informing policy* (generating insights or intelligence for policy): envisioning future challenges and possible policy options, mapping dynamics of change, and structuring policy problems (or supporting policy definition).
b. *Facilitating policy implementation*: The capacity for change within a given policy field can be enhanced through a common awareness of the present situation and future challenges, as well as new networks and visions among stakeholders.
c. *Embedding participation in policy-making*: Improving transparency and legitimacy through facilitating the participation of civil society and private industry in the policy process.
d. *Reconfiguring the policy system*: Preparing the policy system to address long-term challenges.
e. *Symbolic function*: Convincing the public that a particular policy (or policy regime) is based on rational information and evidence.

In general, STI foresight involves systematic attempts to look at the longer-term futures of STI and to generate intelligence on how best to steer STI for the future. It is a useful toolbox for identifying R&I investment priorities that are likely to generate the greatest economic, environmental, and social benefits for the future. In this way, it can be vital to designing sustainability-oriented innovation (SOI) policy frameworks. Private firms and public agencies can deploy foresight to develop specific STI roadmaps and strategies.

The above review of literature shows that foresight has evolved from a narrow focus on identifying future trends in technology to a broader holistic emphasis on social, economic, and environmental dimensions of technological change, with greater focus on generating visions and rationales for long-run STI policy. There is a diverse range of methods that can be deployed in various combinations in STI foresight. Building knowledge of the methods and the capacity to choose and use them is key to enable foresight to inform an impactful STI policy. The choice of methods and how they are deployed is largely determined by the purpose or objectives

of STI foresight. As the illustrative cases in the next subsection show, different developed countries have institutionalized STI foresight by experimenting with different approaches to build foresight capacities and cultures.

2.4 | Illustrative cases of international practices

Dreyer and Stang (2013) and the Organisation for Economic Co-operation and Development (OECD, 2021) provide good analyses of how different countries around the world have institutionalized foresight practices. They show that many governments around the world have established or are establishing institutions (or institutional arrangements, such as networks and departments) that enable them to engage in domestic foresight practices for public policy.

Foresight approaches and methods are also often determined by region and culture. For example, futures workshops are popular in Europe and North America, but are much less prominent in Asia and Oceania, and are not often used in Latin America (Miles et al., 2017). The Delphi method is most often used in Latin America, Asia and Europe, but is not commonly used in North America.

The OECD has established foresight forums (Keenan, 2020). It provides policy support to member governments and hosts the "OECD Futures" forum. Foresight forums are a collaborative effort by policy-makers from member and non-member governments, business, and civil society. The OECD has a forward-looking range of 10–20 years on selected topics related to research and innovation policy. For this, its STI Outlook serves as a discussion platform. The STI Outlook contains the latest trends and issues relevant to STI policy. It is a resource for the OECD's science and innovation policy activities and explores new topics for future projects. The discussion below provides an overview of STI foresight approaches in several OECD countries.

2.4.1 | STI foresight in the United Kingdom

The UK has a relatively rich history and experience of engaging in STI foresight, dating back to the late 1980s and the early 1990s (Martin, 1993). In 1993, the government launched a large-scale UK Technology Foresight Programme following up a White Paper on Science and Technology (Chancellor of the Duchy of Lancaster, 1993). The two main objectives of the Foresight Programme were: (1) to inform decision-makers on the direction of publicly funded R&D; and (2) to help promote partnerships between scientists and industrialists to identify market opportunities and emerging technologies. The programme's range or scope has, over the past decade or so, been broadened from a narrow focus on economic considerations to an increasing emphasis on social and environmental sustainability issues. Decisions on topics to be covered or considered in foresight are made by the government's Chief Scientific Advisor, informed by explicit criteria including: (1) whether the STI foresight exercise will generate new value and involve long-term thinking; (2) whether the exercise or project will fill an evidence gap or inform a new strategy or policy being developed by government; and (3) whether there is a clear demand or articulated customers for the STI foresight project within government.

Mixed methods have been used in most of the UK's STI foresight exercises. The most common or dominant methods are Delphi surveys, horizon scanning, and expert panels. Over the past 20 years or so, more than 30 STI foresight and related reports have been published. The UK government has taken various actions to ensure the implementation of some of the recommendations of the reports. Some of the interventions taken include the establishment of various committees of different STI policy issues. Research councils play key roles in the implementation of recommendations of foresight reports.

2.4.2 | STI foresight in Finland

Finland has institutionalized STI foresight since the 1990s and has supported several developing countries in experimenting with STI foresight and foresight-like initiatives.[1] It is considered one of the leading countries in the design and implementation of STI policies (Saritas & Anim, 2018). Finland has built strong foresight capacities, where foresight functions are distributed among many actors in public, private, and non-governmental spheres (Saritas & Anim, 2018). The country's government prepares and releases one foresight report every four-year electoral period. Every time a new government is elected, it develops an STI vision and policy for its term. The Prime Minister's Office and a ministerial group co-ordinate foresight programmes. The National Foresight Network is run from the Office of the Prime Minister. The network follows an open approach, and foresight presentations, training events, and networking opportunities are offered on a regular basis. Most of the foresight processes in Finland take approximately two years and involve many stakeholders through online surveys known as mini-foresight. A mix of methods, including particularly Delphi, expert panels, and horizon scanning have been deployed in the country for STI foresight.

It is important to note that Finland's STI foresight exercises are often integral to broader national foresight processes co-ordinated by the secretariat of the Prime Minister's Office. The government is legally required to provide and submit a "Report on the Future" to parliament. There is a joint foresight working group in which ministries participate. The ministry responsible for STI is represented in this group and ensures that STI foresight has a chapter in the report.

Another issue to note is that Finland is actively involved in international collaborations on STI foresight. For example, since 2007 Business Finland (formerly the Finnish Funding Agency for Technology and Innovation) and the Japanese National Institute of Science and Technology Policy (NISTEP) have been sharing information and experiences on different foresight methods and gaining new perspectives for addressing societal challenges. In September 2019 they launched a project on the emerging circular economy to share foresight methods, knowledge, and results, and to compare findings in both countries. This initiative aims to foster a model of international foresight collaboration (Business Finland, 2020).

Finland also co-operated with a developing country, South Africa, on a project on STI foresight in the mid-2000s. Between 2006 and 2010, Finland and South Africa developed and implemented the Cooperation Framework on Innovation Systems between Finland and South Africa (COFISA). COFISA's main objective was to enhance the effectiveness of the South African national innovation system to grow the economy and eradicate poverty. Foresight exercises were conducted in three provinces of South Africa (Gauteng, Eastern Cape, and Western Cape). It aimed to inculcate a culture of foresight and innovation strategizing at regional and national levels in South Africa. Through projects like COFISA and other international co-operation initiatives, Finland has been at the forefront of promoting cross-country foresight learning and information sharing.

2.4.3 | Canadian STI foresight

Canada also has a relatively long history of engagement in STI foresight. Dating back to the 1970s, the federal Government of Canada initiated technology foresight and science foresight exercises. In 1973, the Ministry of State for Science and Technology established the Interdepartmental Committee on Technological Forecasting (Miles, 2010). The Committee's initial focus was on identifying technological trends and their impacts on the Canadian economy. It experimented with foresight methods, particularly trend analysis and scenario planning. The

[1]A foresight-like initiative is a non-formal exercise where foresight methodology is used—but not as a complete exercise—to, for example, do strategic planning.

Committee influenced the institutionalization of foresight exercises in various governments and departments, as well as research institutions in the country.

In the 1980s, the Canadian Science Council started technology assessment activities with some foresight approaches. The technology assessments focused mainly on threats and opportunities, as well as the country's strengths or capabilities (Miles, 2010) in generic technologies (such as microelectronics and biotechnology) and strategic sectors such as aquaculture, forestry, and transport. Social and economic trends, market demands, and public perception were also covered. Tools used in the technology assessment included nationwide surveys, expert interviews, workshops, and expert panels.

Over the past three decades or so, Canada has established a variety of other institutional arrangements and programmes for foresight, some have focused on STI issues. They include Policy Horizons Canada, which conducts foresight to assist the federal government in developing future policies and programmes for a wide range of sectors, most of them with STI content or focus. Policy Horizons Canada also commissions and investigates technological evolution and has a wide-ranging impact. It also administers the Metascans series of technology foresight impact reports that are developed with the support of private experts and are made publicly accessible and are promoted. Metascans (e.g. emerging technologies, resilience in transition to digital economy, etc.) explore how the economy and society will be shaped in the future, using mostly horizon scanning, searching for weak signals, realizing that disruptive change often comes from places where analysts are not looking (Policy Horizons Canada, 2013).

Other initiatives include the Changing Maps public service roundtables with significant expert involvement and Canada@150 (2010). Canada's federal government and public service leaders have effectively used advanced contemporary futures methods across many sectors of public administration, for envisioning probable scenarios and define policy options for their emergence. According to Peter (2017), Canadian foresight exercises have focused on large-scale problems and policy issues, such as impacts of new and emerging technologies, steering STI for sustainable development, and sectoral priorities in healthcare and energy. Overall, Canada has widened and deepened its foresight across government departments and broadened the scope of STI foresight to cover a wide range of sustainable development issues.

2.4.4 | STI foresight in the United States

In the US, STI foresight can be traced to the 1960s. The Committee on Science and Public Policy (COSPUP) of the US National Academy of Sciences conducted surveys and assessments of promising scientific disciplines and technological frontiers (Martin, 1995). This built the basis for a more coherent foresight in STI. In the 1980s, the National Research Council (NRC) conducted foresight studies focusing on chemistry and physics. Miles (2010) associates STI foresight in the USA with the Office of Technology Assessment (OTA) established in 1972. The OTA combined technology assessment—assessing risks and benefits—of new technologies with some elements of foresighting. It had a high-level authorization and its reports were submitted and considered by the Congress.

In recent years, the US has institutionalized foresight studies in various organizations. Since the 1990s, the Department of Defense has been conducting foresight in critical technologies. The emphasis of these exercises has been on aspects such as identifying technologies that enhance the US's long-term superiority in military weapons, military technologies that would strengthen the country's industrial base, and R&D areas where the country should strengthen its investment to maintain military hegemony.

Since 1990, STI foresight has also been institutionalized in the Office of Science and Technology Policy (OSTP) at the White House. The OSTP is legally required to produce foresight reports twice a year on the nation's critical technologies and future technological opportunities. The emphasis is also placed on how technologies (and related R&D) would be incorporated into commercial and defence operations within the next 10–15 years. Most of the foresight studies by the OSTP are conducted through expert panels comprising representatives from academia,

industry, and government. The OSTP has also deployed most of the available foresight methods depending on the key questions and issues under consideration.

2.4.5 | STI foresight in Japan

Japan has been conducting STI foresight exercises since the early 1970s (Martin, 1995). Initially, the Science and Technology Agency (STA) was the main national Japanese institution mandated with STI foresight. Through a variety of methods and processes, STA conducted foresight studies looking 30 years into the future of STI. According to Martin (1995), these foresight studies were the most systematic and comprehensive with the objective of informing STI policy and planning. In 1995, the fifth foresight study was undertaken by the National Institute for Science and Technology Policy (NISTEP), and since then large-scale studies are conducted roughly every five years (Cameron et al., 2019).

Japanese foresight exercises are participatory, involving a comprehensive range of stakeholders. NISTEP has a high-level committee that is responsible for setting the agenda and authorizing the results of foresight. Specialized teams or committees are also established to provide technical expertise on specific issues. A combination of methods is used in the Japanese STI foresight exercise, though the most prominent is Delphi surveys. For the 11th foresight conducted in 2019, NISTEP combined forecasting and backcasting approaches to create a conceptual scenario that includes the future vision of society, relevant science and technology (S&T), and societal issues to consider (NISTEP, 2019). The study also found eight interdisciplinary STI areas to be promoted through natural language processing and experts' judgment. The results were compiled into a summary report and five-volume reports, one each on horizon scanning, visioning, Delphi survey, exploring interdisciplinary S&T areas, and scenario building.

Over the past three decades or so, topics that have been covered are STI for global challenges include HIV (with emphasis on vaccine development), energy insecurity and climate change, and the future of or trends in emerging technologies such as Artificial Intelligence (AI). According to Saritas and Anim (2018), Japan has the longest-running STI foresight programmes in the world. There have been changes in the content and processes in parallel with new and emerging STI areas.

2.5 | Synthesis of issues and lessons from international illustrative cases

All five examples or cases presented above show that the institutionalization of STI foresight has been gradual or incremental in the sense that the countries started with programmatic initiatives that were initially narrow in scope around technology foresight and later expanded to cover a wide array of STI issues. To a large extent, there has been cross-country learning. For example, the co-operation between Finland and Japan, and the UK's programme drew lessons from the US's technology assessment under OTA and, later, foresight, being domiciled in the White House Office of Science and Technology Policy.

The developed country examples also show that foresight exercises need to be purposefully linked to or integrated with specific STI policy processes, either informing the design and/or implementation of policy. These countries have not invested in foresight for its own sake. They have had specific institutional arrangements to ensure the implementation of foresight recommendations or the use of foresight outputs. STI foresight exercises are designed and implemented taking into account specific users' needs. There is a specific articulated demand for and high-level authorization of foresight.

The Canadian and Finnish cases demonstrate that STI foresight should not be the preserve of one agency. A whole-of-society (and whole-of-government) approach is crucial to widening and deepening STI foresight to ensure broad-based ownership of the processes and outputs of foresight exercises.

Another important lesson is that developed countries have tended to use a diverse mix of foresight methods chosen depending on their own specific contexts, including economic costs, infrastructure and policy culture, as well as specific objectives of each foresight exercise. This means that they have been flexible and adjusted foresight exercises depending on their needs and changing circumstances.

3 | METHODOLOGY

Based on the review of the literature on conceptualization of STI foresight, its key features and usefulness, and drawing on the five illustrative developed country examples, the rest of this study covers trends in and capacity needs for STI foresight in SSA with emphasis on 17 countries that are members of the Science Granting Council Initiative (SGCI). The SGCI is a multilateral initiative established in 2015 to strengthen the institutional capacities of public science funding agencies in sub-Saharan Africa to support research and evidence based STI policies.

Guided by the review of literature, a survey questionnaire was designed to gather empirical information on the understanding of STI foresight and different foresight methods, whether their institutions and/or countries had bodies dedicated to STI foresight, what STI foresight capacities exist and informants' recommendations on ways and means to build STI foresight. The questionnaire (in both English and French) was sent to the 17 focal points of the participating countries. Nine focal points completed and returned the questionnaire.

A bibliometric analysis was conducted to gather "indicative" empirical information on the productivity of research on STI foresight in and from SSA, as well as SSA researchers' participation in international research on STI foresight and related areas. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Framework was used. The framework involves the following four steps: identification; screening; eligibility; and inclusion (Liberati et al., 2009).

Tentative findings from the literature review, initial interviews, and bibliometric analysis were all presented at a Masterclass on STI foresight that was organized by the SGCI in Cape Town on 5 December 2022. The Masterclass participants were from the SCGI institutions, international funders, policy-makers from departments of STI, and academics and researchers from various institutions, including universities. Focused group discussions and plenary sessions generated additional empirical information on countries' capacity needs and proposals for building STI foresight.

4 | FINDINGS ON STI FORESIGHT CASES AND CAPACITY NEEDS IN SSA

4.1 | Continental and national STI foresight initiatives

There are relatively few cases of STI foresight initiatives or efforts in SSA. Some STI foresight-related exercises were undertaken at the continental level through the AU and the then New Partnership for Africa's Development (NEPAD) during the development of Africa's Consolidated Plan for Science and Technology (CPA) between 2003 and 2005, and the Science, Technology and Innovation Strategy for Africa (STISA-2024) between 2011 and 2013. During the development of the CPA, NEPAD organized participatory processes involving SWOT analysis, horizon scanning, and Delphi to identify specific regional R&D priorities and future technological opportunities for Africa within a five- to ten-year vision. Expert panels on biotechnology, nanotechnology, and space sciences were convened to foresight the long-term benefits and costs of Africa's investments in these fields.

For the development of STISA-2024, foresight-related activities included expert panels brainstorming about R&I priorities that Africa should invest in to realize its long-term aspirations, as articulated in Agenda 2063. The AU Commission co-ordinated this effort, which was largely technocratic, with limited participation of national

TABLE 1 STI foresight in South Africa.

Year	Scope and purpose of foresight
1990–2000	National Research and Technology Foresight (NRTF), identification of technologies and technological trends likely to have the greatest impact on the country's social and economic development
2001–2010	To identify grand challenges for the 2008–2018 Ten-Year Technology/ Innovation Plan
2018–2019	Identify strategic R&I priorities for the 2021–2031 STI Decadal Plan for the implementation of the 2019 White Paper on Science, Technology and Innovation

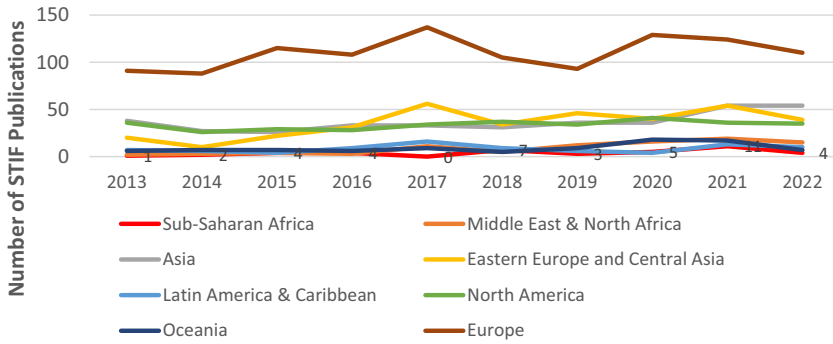

FIGURE 1 Trends in STI foresight publications in SSA and other regions.
Source: computed from a Scopus database

departments for STI and regional economic communities. However, both the CPA and STISA-2024 initiatives were authorized at ministerial and presidential levels at AU summits.

Two SSA countries—South African and Botswana—have participated in national STI foresight exercises. Only South Africa has conducted several (three) STI foresight exercises. Its foresight exercises have been conducted mainly to inform, or as inputs into, STI policy and plans. International experts from Russia, Finland, and the United Kingdom have been used to lead or conduct the foresight exercises in the country (see Table 1).

Botswana conducted a rapid STI foresight in 2022 with the support of the United Nations Conference on Trade and Development (UNCTAD). It involved three one-day workshops that brought together stakeholders: mainly government officials and researchers. Horizon scanning, causal layered analysis, and scenario planning were the main methods deployed in the foresight. The Department of Research, Science and Technology (DRST) co-ordinated the exercise.

4.2 | Status of SSA's research publications on STI foresight

Based on the biometric analysis, research into and for STI foresight is still much in its infancy in sub-Saharan Africa. As Figure 1 shows, SSA has significantly fewer STI foresight publications than comparable regions. In 2022, Europe had 110 publications, followed by Asia (54 publications), Eastern Europe & Central Asia (39 publications), and North America (35 publications). In total, 41 publications related to STI foresight were produced in SSA between 2013 and 2022. This is equivalent to about 1.8% of the world's publications on STI foresight (2,219) during 2013–2022.

Approximately 69% of all SSA's STI foresight publications (38) have at least one author from South Africa. This is followed by Nigeria (9; 16.4%), Kenya (6; 10.9%), and Ghana (4; 7.3%). It can be deduced from Figure 2 that

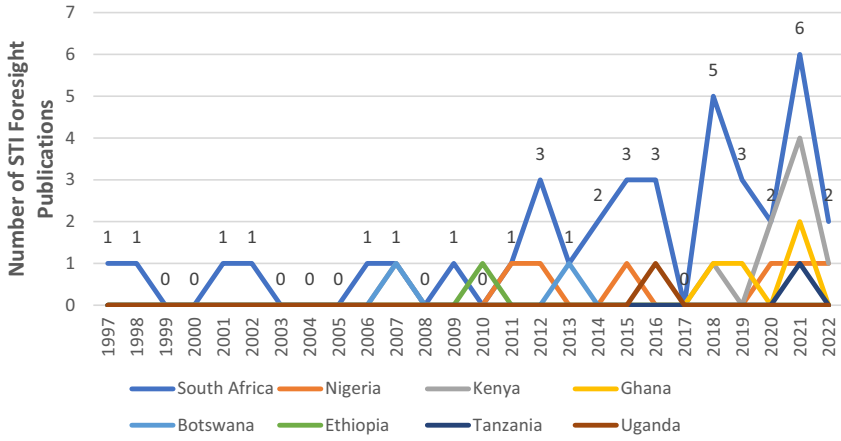

FIGURE 2 Trends in STI foresight publications in SSA by country.
Source: computed from a Scopus database

of 46 SSA countries, very few are engaged in research related to STI foresight, at least in terms of publishing in international peer-reviewed journals.

Although Kenya and Nigeria follow South Africa in the number of publications related to STI foresight, neither country has a documented history of conducting STI foresight exercises. Of the nine Scopus publications from Kenya and the six from Nigeria, none focuses directly on STI foresight, but various aspects of foresighting and foresight methods are used. However, two papers with at least one author from Kenya cover the areas of horizon scanning (Esmail et al., 2020) and a Delphi study (Begemann et al., 2021). This shows that, while there is limited academic research on foresight in STI fields in Kenya and Nigeria, there are concrete STI foresight practices in these countries.

A growing number of researchers based in SSA are co-publishing with their counterparts in the top 10 countries leading foresight or futures studies in general, as Figure 3 and 4 below shows. Over the years, the researchers from SSA co-published more with those in the US, although there is increasing collaboration with other countries. In 2021, researchers in the UK had a 23.5% share, followed by the US (21.7%), India (14.8%), China (13.9%), and Australia (13.0%) co-publications with SSA researchers.

Many of the publications have focused on or covered different foresight methods and the application in various sectors such as energy, health, and agriculture. Of all the 945 SSA STI foresight-like initiatives publications covered in Scopus during 1986–2022, scenario planning has a share of 25.7% (407 publications), followed by technology roadmapping (28.9%) and Delphi method/technique (15.1%). The oldest of these STI future-planning tools in SSA are scenario planning, Delphi methods/techniques, long-range planning, and technology roadmaps.

In 2000, the main subject areas for the STI foresight initiatives publications in SSA were agriculture and biological sciences (66.7% of all the publications), followed by earth and planetary sciences (22.2%). Engineering publications dominated in 2001 with a share of 66.7%. In 2021, the percentage share of these publications was as follows: medicine (29.3%), engineering (21.1%), environmental science (21.1%), social sciences (16.5%), agricultural & biological sciences (16.5%), computer science (12.8%), energy (12.0%), biochemistry, genetics, and molecular biology (9.0%), business, management, and accounting (8.3%), earth and planetary sciences (6.0%) and other subject areas (5.3%). The sum of the total share of publications in these subject areas exceeds 100% as one publication can cover more than one subject area.

In summary, the bibliometric analysis shows that, although relatively low on a global scale, SSA's research publications on STI foresight have been increasing over the past decade or so. South Africa leads on research on STI foresight and has accumulated practical experience in conducting foresight exercises. Nigeria, Kenya, and Ghana have produced relatively small numbers of research publications, but have demonstrated practice

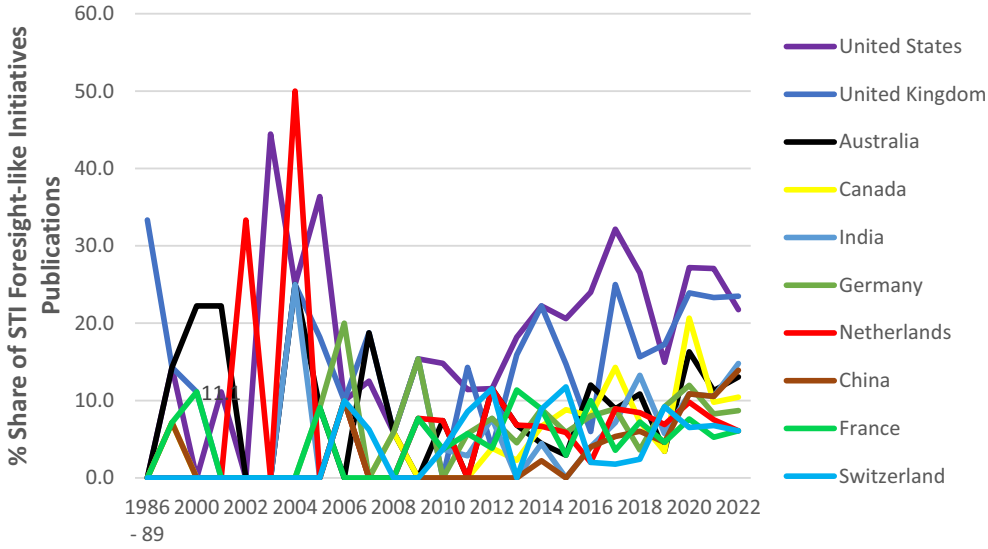

FIGURE 3 Trends in global co-publications involving SSA with the top ten countries in the world. Source: computed from a Scopus database

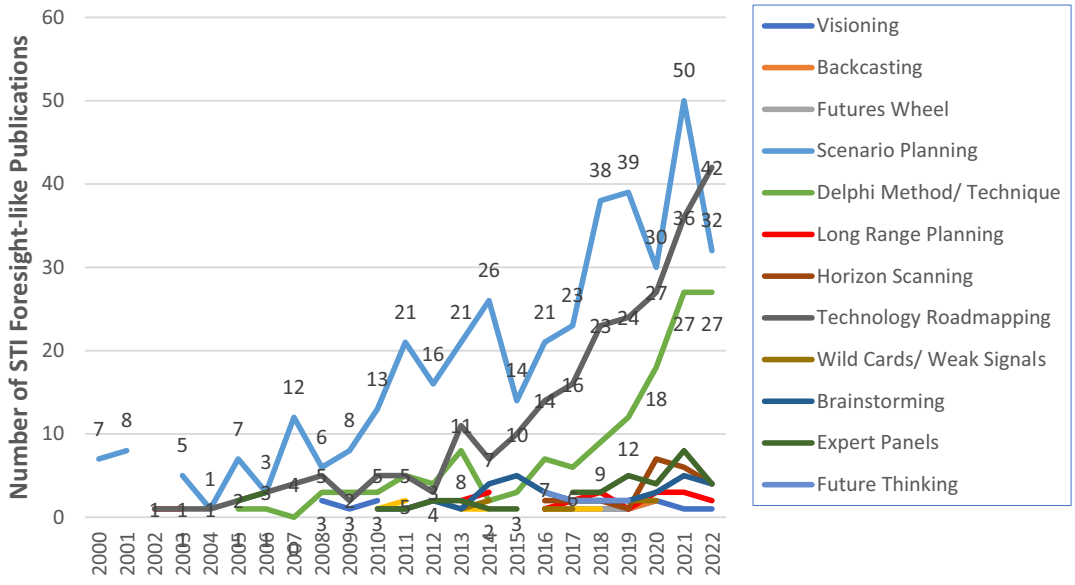

FIGURE 4 Foresight methods in publications trends in SSA. Source: computed from a Scopus database

in STI foresight. Overall, the participation of SSA countries in international research on foresight increased over the past decade, as shown by increasing co-publishing with 10 leading developed countries engaged in foresight research. However, there is no evidence that increasing research publications by some SSA countries and/or their participation in international research on foresight is stimulated by or is linked to national practical STI foresight exercises.

4.3 | Foresight capacity needs of SGCs in SSA

From the survey, interviews, and discussions at the Masterclass, there is adequate evidence that most SSA countries in the SGCI community are interested in or intend to conduct STI foresight exercises. Some of the countries are required by national STI policy to institutionalize foresight and related Technology Assessment (TA) as tools for policy development and implementation. At least two countries have adopted STI policies and action plans that require them to institutionalize and/or conduct foresight. South Africa's 2019 White Paper on Science, Technology and Innovation requires that its 10-year implementation plans be informed by foresight studies (Department of Science and Technology, 2019). The National Advisory Council on Innovation (NACI) is required to establish monitoring and evaluation (M&E) frameworks and conduct regular foresight exercises (Department of Science and Technology, 2019). From interviews with two NACI officials, there is a plan to establish a national centre dedicated to STI foresight as a response to the policy requirements.

Namibia's 2021 National Science, Technology and Innovation Policy 2020–2030 and its National Action Plan (2023) have provisions that require the National Commission for Research, Science and Technology (NCRST) to conduct foresight studies focusing on frontier technologies, particularly artificial intelligence and R&I priorities in the Blue Economy. The Namibia's Blue Economy Policy provides a basis for leveraging the full potential of Namibia's aquatic ecosystems in order to address its socio-economic needs in an environmentally sustainable manner (Ministry of Fisheries and Marine Resources, 2022). Weak institutional capacity, low levels of awareness of foresight, no dedicated budget, and scarcity of technical expertise were identified by one interviewee as major barriers to institutionalization of foresight in Namibia.

Respondents to the survey questionnaire, interviewees and discussions at the Masterclass identified various impediments to institutionalizing and conducting STI in their respective countries and SGCs. Table 2 is a summary of the impediments.

Overall, SSA countries have systemic capacity barriers to institutionalizing STI foresight. The countries and their SGCs have no dedicated funds and lack critical technical and institutional capacities, as well as active public and political constituencies for STI foresight. However, some of the SGCs and the SGCI have

TABLE 2 Barriers to institutionalization of foresight in SSA.

Type of impediment	Specific barrier
Human resources	• Limited expertise/skills in foresight in the SCGs and countries generally • Over-reliance on external foreign experts • Most of the foresight methods are unknown to SGC officials as foresight conceptualized in the developed world
Institutional arrangements	• Weak co-ordination between SGCs and national legislature hinders authorization of foresight • Limited links between universities/researchers working on foresight and departments of STI • Lack of agencies or institutes mandated to conduct foresight • No training courses or programmes for foresight in SSA
Financial	• No budgets or funds allocated to foresight • Reliance on external funding for STI and R&D programmes
Political	• Weak political support for STI policy and STI foresight
Public constituency	• Low levels of awareness of foresight and its utility • No clear articulation of public demand for STI foresight and R&D plans
Conceptualization	• STI foresight and its methods were conceptualized and/or developed in developed countries with different policy cultures and resource endowments. They are not fit for purpose in SSA country settings without adjustments or modifications

recognized the need to institutionalize STI foresight—hence there is a need to support them to build the necessary capacities.

5 | CONCLUSIONS

There are several lessons that SSA countries should learn from international practices in STI foresight. First, there is need for clarity in the conceptualization of foresight and STI foresight. Different policy cultures have different ways (conceptual lenses and metaphors) of and means for envisioning possible futures and framing anticipatory policies or decisions for or about the future.

Second, foresight should be authorized at the highest levels of executive and political governance. By this it is meant that countries (or regions, such as the EU) that have had STI foresight institutionalized, well organized and in regular use, are those where such foresight exercises have been sanctioned or approved by parliaments and are co-ordinated in or by offices of the prime minister or even the president, and where there is a competent authority designated for foresight.

Third, adequate time, funding, and human resources need to be dedicated to foresight. The illustrative cases show that a properly organized and implemented STI foresight exercise takes between two and three years depending on the size of the NSI and the scope of the foresight. Building the requisite institutional capacities to manage or administer foresight is thus a priority if any SSA country is to effectively engage in and with STI foresight.

Fourth, foresight exercises should be organized as processes involving negotiation between different interest or stakeholder groups, building consensus, and creating commitment to national R&D and innovation priorities. They should not be organized as discrete or isolated activities led by technocrats. Foresight should be embedded in STI policy processes at all levels of governance in countries.

In conclusion, this article shows that STI foresight is in its infancy in SSA. Only two countries among the SGCI members in SSA have conducted STI foresight, led by South Africa. However, there is increasing interest in institutionalizing STI foresight in SSA, particularly among SGCI members. There is also increasing academic research on foresight that can help to spur and inform STI foresight exercises in the region. The article argues that, as more countries in SSA focus on developing and implementing STI policy, the demand for foresight capacity will increase. Governments of SSA countries and funders should partner through initiatives such as the SGCI to build the requisite technical and institutional capacities for STI foresight. Key areas of capacity building include research to conceptualize STI foresight and develop methods for specific low resource contexts of SSA, raising awareness of different STI foresight methods and building skills to use them.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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