



Gender-based assessment of Science, Technology and Innovations ecosystem in Sudan

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ABSTRACT

Science, Technology and Innovations (STI) play a critical role in each of the Sustainable Development Goals (SDG). Despite several STI initiatives to ensure achievement of the 5th Sustainable Development goal on gender equality, the participation of women in STI has remained low all over the world in general but particularly in sub-Saharan Africa (SSA), where women are greatly underrepresented in STI ecosystem. In Sudan, there are Policies and Strategies for STI in the Ministry of Higher Education and Scientific Research but there is no mention of gender or gender equity as separate issues. The female students at Sudanese higher education institutions form the majority (55%) of enrolment at undergraduate level and in some cases reaching 70-80% as in Agriculture and Medical fields, while enrolment of female in Science, Engineering and Mathematics is less than 23%. The numbers of females at universities and research institutes decrease in high seniority levels, with only 15 female professors out of 95 professors in research institutes in 2017. In Sudanese universities there is only one female professor in engineering in the academic year 2017/2018, while in the broader science fields there are only six female professors out of 53 professors. The women involvement in decision making in academia and industry is negligible, and overall women scientists involved in leadership and their participation in research and development is low. There are only three women Vice Chancellors out of 133 university Vice Chancellors. According to the new constitution representation of women must increase to 40% of government workforce as a general policy. The financial support of STI research in Sudan depends mainly on the public sector (more than 95%) compared to a very low contribution from the private sector. Nowadays, there are new policies at the Ministry of Higher Education and Scientific Research for partnership with the private sector by using the infrastructure of industrial companies for some STI initiatives. The overall findings from this study indicate that in Sudan the gender participation in STI issues are not well emphasized in policies and strategies of STI. However, there are some initiatives through non-governmental organization such as Sudanese Women in Science Organization and STEM Girls' clubs project to stimulate and enhance women participation in STI programs.

Key words: Gender, STEM, STI, Sudan, women participation

RÉSUMÉ

La science, la technologie et les innovations (STI) jouent un rôle essentiel dans chacun des objectifs de développement durable (ODD). Malgré plusieurs initiatives STI pour assurer la réalisation du 5ème objectif de développement durable sur l'égalité des sexes, la participation des femmes aux STI est restée faible dans le monde en général, mais en particulier en Afrique subsaharienne (ASS), où les femmes sont largement sous-représentées dans les écosystèmes STI. Au Soudan, il existe des politiques et stratégies pour les STI au sein du ministère de l'Enseignement supérieur et de la Recherche scientifique, mais il n'y a aucune mention du genre ou de l'égalité des sexes en tant que questions distinctes. Les étudiantes dans les établissements d'enseignement supérieur soudanais constituent la majorité (55%) des inscriptions au premier cycle et atteignent dans certains cas 70 à 80% comme dans les

domaines de l'agriculture et de la médecine, tandis que les inscriptions des femmes dans les sciences, l'ingénierie et les mathématiques représentent moins de 23%. Le nombre de femmes dans les universités et les instituts de recherche diminue avec les niveaux de séniorité avec seulement 15 femmes professeurs sur 95 professeurs dans les instituts de recherche en 2017. Dans les universités soudanaises, il n'y a qu'une seule femme professeur en génie au cours de l'année académique 2017/2018, tandis que dans les domaines scientifiques plus larges, il n'y a que six femmes professeurs sur 53 professeurs. La participation des femmes à la prise de décisions dans les universités et l'industrie est négligeable et, dans l'ensemble, les femmes scientifiques impliquées dans le leadership et leur participation à la recherche et au développement sont faibles. Il n'y a que trois femmes recteurs sur 133 recteurs des universités. Selon la nouvelle constitution, la représentation des femmes doit atteindre 40% de l'effectif gouvernemental dans le cadre d'une politique générale. Le soutien financier de la recherche STI au Soudan dépend principalement du secteur public (plus de 95%) par rapport à une très faible contribution du secteur privé. De nos jours, il existe de nouvelles politiques au sein du ministère de l'Enseignement supérieur et de la Recherche scientifique pour un partenariat avec le secteur privé en utilisant l'infrastructure des entreprises de l'industrie pour certaines initiatives STI. Les conclusions générales de cette étude indiquent qu'au Soudan, la participation des femmes et des hommes aux problèmes liés aux STI n'est pas bien mise en évidence dans les politiques et stratégies des STI. Cependant, il existe des initiatives par le biais d'organisations non gouvernementales telles que l'Organisation des femmes soudanaises dans les sciences et le projet des clubs de filles STEM pour stimuler et améliorer la participation des femmes aux programmes de STI.

Mots clés: Genre, STIM, STI, Soudan, participation des femmes

INTRODUCTION

Science and Technology (S&T) are the key drivers of economic and social development, and this has been clearly emphasized in the recently published reports of the Scientific Advisory Board of the Secretary-General of UNESCO (SAB, 2016). Key components of the concept of innovation include the role of knowledge as a basis for novelty, utility, and value creation or preservation as the presumed goal of innovation. The Innovation can signify both an activity and the outcome of the science and technology research activities and play a vital role in determining or influencing growth and development (Sawahel, 2014; Oslo Manual, 2018). According to the United Nations (UN, 2015), sustainable and inclusive development are incomplete without a full consideration of issues of Science, Technology and Innovation (STI). Access to new and appropriate technologies promote steady improvement in living conditions, which can be life saving for the most vulnerable

populations, and drive productivity gains which ensure rising incomes (Abdelmawla, 2010; and Molnár, 2015). The STI policies became the main driver in increasing the productivity, job opportunities, growth and delivering services in public and private sectors (Nour, 2012). Both Research and Development (R&D) and Innovation have the potential to significantly contribute to Africa's economic growth and prosperity. Hence, there is a need to demonstrate the use of science, technology and innovation in poverty reduction, job creation, sustainable livelihoods and improved well-being of African citizens.

Africa is lagging behind the other regions of the world in terms of STI because of the low investment in technology in general and low expenditure on research and development (R&D) in particular. According to AIO III (2019) understanding of STI systems is important for research and innovation policy formulation and program design. In this regard

the African Science, Technology and Innovation Indicators (ASTII) initiative has made progress in supporting African countries to collect data on STI indicators and generate new indicators for better understanding of STI situation. This is particular so with focused and sustained human capital development through higher education (Borland and Dawkins, 2000; Bloom and Canning, 2006; Montengero and Patrinos, 2013).

Sudan's science and technology development agenda started with the establishment of the first R&D laboratory (The Welcome laboratory) in 1902 and the Agricultural Research Station in 1904. In 1924 Kitchener School of Medicine was started, as nucleus for University of Khartoum (AbuGokh, 2015). The National Council for Research (NCR) was established in 1970 as a governmental body responsible for formulating policies and plans and coordinating national efforts in respect of S&T (Beshir, 2017). The NCR was converted to the Council for Higher Education and Scientific Research in 1991-1992. The Ministry of Science and Technology (MOST) was established in 2001, leading to the formulation of the national strategy for S&T and to the centralization of the public research institutes under its supervision (MOST, 2009). In 2015, the ministry was abolished (ESCWA, 2016), on account of having failed to coordinate the various diverse fields of research to meet the needs of the various ministries and industries. This was mainly because the research institutes have their own mandates strongly related to the research needs of the technical ministries. The main four STI key players in Sudan are Agricultural Research Corporation (ARC) and Livestock Research Corporation (LRC) at the Ministry of Agriculture and livestock, National Information Centre at the Ministry of Communication and Information Technology (CIT), National Research Centre and Universities and research Institutes at the Ministry of Higher Education and Scientific Research (MOHE), and Industrial Research and Consultation Centre at the Ministry of Industry in addition to some

private sector centres (Hassan, 2009).

The STI play a critical role in each of the Sustainable Goals (SDG), but despite several STI initiatives to ensure achievement of the 5th Sustainable Development Goal on gender equality, the participation of women in STI has remained low all over the world in general and particularly in sub-Saharan Africa (SSA), where women are greatly underrepresented in STI system (Tizikara *et al.*, 2019; Zinnah and Jackollie, 2020). The under-representation of women in STI could be attributed to, among other reasons, policy, institutional and individual (cultural) factors. Many countries have gender sensitive STI policies that aim at promoting the participation of women in science at all levels, but these are rarely implemented. The institutional factors include; inflexible working hours, limited support for women in entrepreneurial development and hidden discrimination. Gender biases in the teaching of STEM subjects, family commitments and marriage, lack of confidence, fear of the unknown, lack of role model and mentoring are main cultural factors that hinder the girls and women participation in STI (SAGA, 2018; Tizikara *et al.*, 2019).

In Sudan, female students form the majority (55%) of enrolment at undergraduate level in higher education institutions and in some cases even reaching 70-80% in agriculture fields, while enrolment of girls in Science and Mathematics is less than 40% (Statistic Unit, MOHE reports and UNESCO, 2015). The women involvement in decision making roles in academia and industry is far less, there are few women scientists involved in leadership and their participation in research and development is also low (SAGA, 2018). In Sudan there is a national STI policy and framework but it does not address gender issues significantly. Therefore efforts to ensure greater inclusion of women in the STI in Sudan are highly needed.

Within the above context, the aim of this paper is to conduct a Gender-based assessment of STI

ecosystem in Sudan. The paper is organized in the following sections: Firstly Methodology approaches used to gather information and the key data assessed. This is followed by a presentation and discussion on the status of Science, Technology and Innovation system in Sudan, providing a policy overview and gender perspective. The follow up section examines the status of women participation in STI ecosystem in Sudan including women access and participation in higher education institutions and women participation in STI. This is followed by a discussion on Gender and STI strategies in Sudan including best practices (supporting bodies) at different institutions for enhancing STI performance and promoting female participation in STI, and subsequently a section on Gender and Scientific performance in Sudan. The final section presents Future prospective on Gender participation in STI in Sudan and needed action to increase women participation in STI and indeed in the broader development landscape in Sudan

METHODOLOGY AND ACTIVITIES

The methodology adopted relied on a cross section of information sources using quantitative and qualitative methods. Gender policies and strategies of STI in Ministry of Higher Education and Scientific Research (MOHE) and other related institutes as well as reports on gender initiatives in the country were reviewed to assess the gender gap in STI. Data on female enrolments and graduation in the Higher Education Institutions (HEIs) were analyzed to provide an overview of female participation in higher education and STI. Additional information was collected through interviews using different formats, face to face, emails and phone call interviews with key informants from the Ministry of General Education, Ministry of Higher Education and Scientific Research, University of Khartoum, AlNeelain University, University of Gezira, Kordofan University, Africa City of Technology, National Council of Research, Agriculture Research Cooperation, Sudanese Women in Science Organization (SWSO),

UNESCO Chair for Women in Science and Technology-Sudan University of Science and Technology, in addition to 20 experts in the government and private sectors and samples of postgraduate students in STEM fields (Table 1).

For the analysis of female participation in HEIs and STI initiatives, data from 1990 to 2018 were collected to characterize the trends of female participation in HEIs and STI ecosystem. The paper is confined to the last 10 years as of December 2019. From the interviews with different actors the paper captured their perception about the STI situation in Sudan, women participation and gender equity and the opportunities and challenges faced by Sudanese women in the STI ecosystem.

FINDINGS

Science, Technology and Innovation system in Sudan: policy overview and gender perspective. In 2016 the Council of Ministers of Sudan approved a new STI policy which is being translated into strategies and plan of actions with clear priorities. Subsequently, the Ministry of Higher Education and Scientific Research was mandated by government to lead the STI issues for the future sustainable development in Sudan. Government also supported this mandate by attaching all research, development, technology transfer and innovation institutes under MOHE administrative structure, which were previously under MOST. The MOHE created new units for Scientific Research and Innovation Commission as a body for Sudan STI policies, plans and strategies and to coordinate STI initiatives. Accordingly, the structure of STI is categorized at four main ministries, i.e., MOHE, Information and Communication Technology (ICT), Industry (including private sector), and Agriculture and Livestock ministries. At the ministerial level, most of the funding bodies were allocated a clear distinction between each other and the coordination between and cross entities are usually done at ministries council level.

Table 1. Summary of data collection process

Data and information collected	Method/activity	Source
Gender policies and strategies in higher education; Priorities and interventions National debate about national education system and S&T	Literature review	Ministry of Higher Education, National Research Council, Ministry of Information and Communication Technology, Africa City of Technology, other related STI institutes, UNESCO Chair for Women in Science and Technology-Sudan University of Science and Technology Peer review articles
Admissions and graduates by sex (% of female enrollment and graduates in STI); Number of researchers by sex Number of academic staff by sex Share of GDP devoted to STI research Indicators for STI situations	Secondary data and Descriptive statics analysis	Ministry of Higher education and Scientific Research (Statistic Unit) Annual reports (2009-2018) Data provided by HEIs, SWSO, UNESCO Chair for Women
Mapping of existing Gender and STI initiatives, main actors and their contribution Women participation in STI initiatives	Documents analysis and interviews	Annual Reports Key informants, Websites
Best practices, challenges and opportunities for improving gender in STI Future for women participation in STI.	Compilation of secondary data and interviews.	Key informants from relevant ministries, HEI, relevant stakeholders from government and private sector were interviewed.

For this paper, the STI Policies for Ministry of General Education, Ministry of Higher Education and Scientific Research, Ministry of Security and Social Development, and Ministry of Information and Communication Technology (ICT) were reviewed. It is observed that there is no STI national policy or framework in the Ministry of General Education and Ministry of ICT. However, the MOHE developed an STI framework “Policies and Strategies of Science, Technology and Innovation” but there is no mention of gender or gender equity as separate issues. The gender equity appeared in the framework of Ministry of Security and Social Development (National Policy of Women Empowerment 2007, updated in 2018) but there

is no clear focus on STI issues in general and gender issues in particular.

Status of STI ecosystem and women participation in Sudan. For this section data from the different ministries involved in STI were collected and interviews with the experts in the government and university staff in public and private universities, research institutes and private sectors were conducted to assess the situation of women participation in STI.

Women access and participation in higher education institutes. The Government of Sudan has made remarkable progress in higher education during the last three decades. The

number of universities increased significantly from five public universities in 1989 to 59 universities (38 private and 21 public) and an additional 74 (up from 2) private colleges and HEI in 2019 (Table 2). This led to significant increase in both students' enrolment and graduation rates in higher education and universities by 73.78% and more than 200%, respectively. The number of students' intake at bachelor level jumped from 6,080 in 1989 to 43,477 in 2007 and to more than 180,000 in 2019. The number of female students rose from 40% of enrolment in 1995 to more than 70% in some colleges in 2019 (Statistics Unit, MOHE).

In Sudan, despite the significant expansion of higher education institutes and graduate training from 1990 to 2019, still the Sudanese universities produce significantly more graduates in social sciences and humanities than graduates from engineering and other sciences. In the year 2016/2017 about 67,357 students graduated in social sciences, while only 15,958 graduated from science and 13,434 from engineering fields at the undergraduate level. There are many reasons behind this gap in graduation in different disciplines. In the first place it has to be realized that there is an equal chance for students to choose the subjects for Sudanese Secondary exam but some public universities offer some engineering fields for boys only (e.g. Survey, Petroleum and Excavation Engineering) and most of the private universities and colleges do not offer studies in engineering or science fields. In 2018 the number of faculties for Engineering and Science in public and private institutes were 56 and 70, respectively which is far below

the Humanities and Social Science faculties, which had about 150 and 85, respectively.

The graduates available at the country level to enter the workforce, including R&D staff numbers, particularly in S&T fields is considered a good human resources indicator to measure the status of the STI in the country. In Sudan, the number of the postgraduate students increased from 1,074 (85 PhD. and 989 MSc) in 1991 to 32665 (6,194 PhD and 26,471 MSc) in 2017 (AbuGokh, 2015; Statistics Unit, MOHE, 2018). However, only 2,064 postgraduate students carried out research work in the field of science and 2,292 in the field of engineering, which represented only 13.3% of students. From the interviews with Sudanese experts and policy makers they mentioned that many graduates lack skills of using modern tools and equipment due to many reasons including low investment by the government and private sector in R&D in addition to the American sanctions, which hindered the development and upgrading of laboratories and other research facilities.

The number of female students at the Master's level during 2010 to 2017 ranged from 41% to 52% of students in the field of Science and 31% to 46% of students in the field of Engineering. However, female students outnumbered male students in Medical field, where they represented 44%-66% of the students, while in the Agricultural field, female students at the master level increased during 2014/2015-2017/2018 to 58% of the students enrolled and this is due to the fact that more than 70% of research assistants are females in the Agricultural Research Corporation (Figure 1).

Table 2. Higher Education Organizations

Type	1989	2019
Public Universities	5	38
Private universities	-	21
Private colleges and institutes	2	74

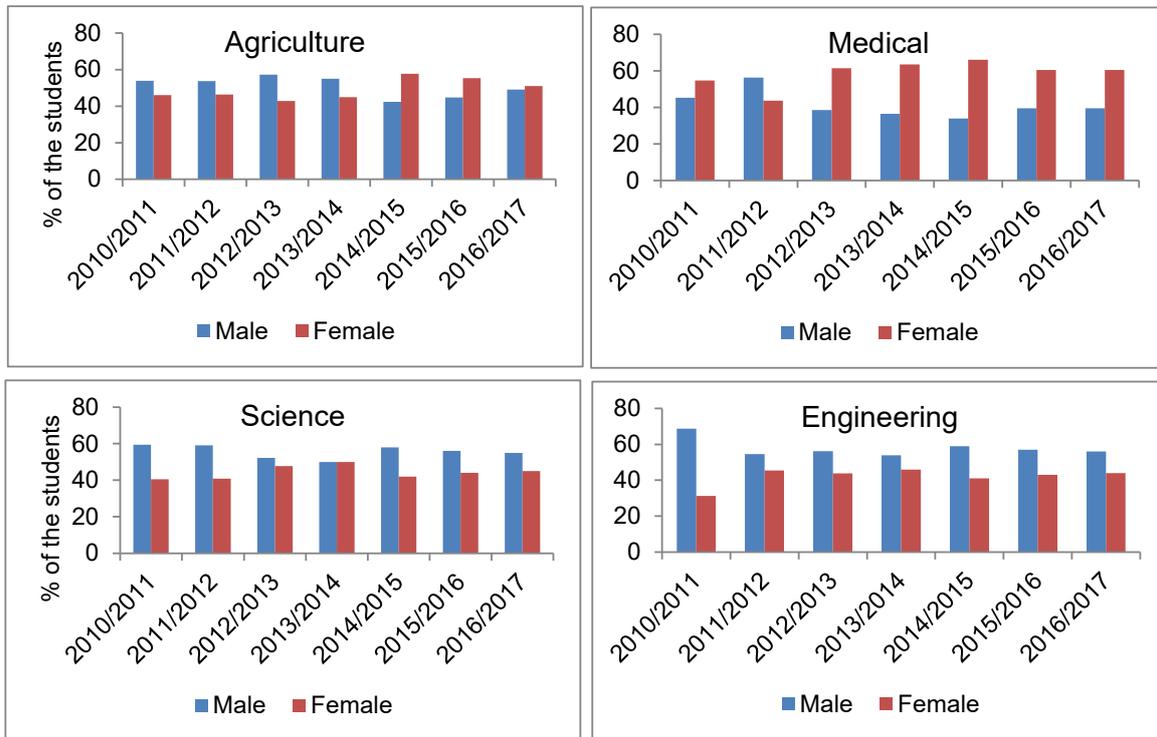


Figure 1. Percentage of female and male students at the master level in science, engineering, agriculture and medical faculties

At the doctoral level, the number of female students increased only in the medical field from the academic year 2010-2011 to 2016-2017 by 40% -63%. However, male students outnumbered female students in the agricultural field. In the field of science, the number of female students increased from the academic year 2010/2011 to 2016/2017 where they represented 21%-43% of the students' population. The percentage of female students at the doctorate level in the engineering field was far below that of male students, where they constituted only 11%-26%. Overall, more male students are enrolled in postgraduate studies in the fields of agriculture, science and engineering and the number of female students is decreasing with ascending steps in the ladder of higher education (Figure 2).

Women in the STI workforce and professional practice. Despite the growth in the number of university staff members, researchers and development personnel, the data from MOHE

indicated that males still dominate positions with virtually no female representation at some institutions in general and at high-ranking positions in particular. During the period from 2009 -2018, the female university staff members represented 24% to 36% of the staff in the Sudanese universities. The number of male staff members at all staff levels (lecturer, assistant professor, associate professor and full professor) exceeded those of female staff (Figure 3). The same situation is true for research institutes. The number of females decrease in high seniority levels. There are only 15 female professors out of 95 professors in research institutes. The numbers of female staff decrease in higher level positions with only one female professor in engineering in the academic year 2017/2018. Similar results were observed in the science fields with only 6 female professors out of 53 (Figure 4). Generally, universities located in Khartoum, Sudan capital, have higher number of professors and associate professors compared with universities located in other states. For

example, in Kordofan University which is located in Kordofan State in Western Sudan, the total number of female staff members was 320 out of 740. There was no female professor and only one female associate professor in the Faculty of Agriculture (Figure 5).

As shown in Figures 3-5 and the information from the interview with key informants, there are few women in high seniority levels mainly due to cultural factors (women not allowed to travel abroad on their own in some areas), family commitments and marriage, lack of confidence, fear of the unknown, hidden discriminations and lack of mentoring and coaching. In the last five years the situation of employing women in higher positions improved. After the December revolution in 2018, the representation of women in STI high ranking positions increased to three Vice Chancellors, while the number of Deans increased to nine in AlNeelain University and

eleven in Sudan University of Science and Technology. This was made possible through the new constitution, which demands that the representation of women must increase to at least 40% of government workforce as a general policy.

STI strategies and gender incorporation in Sudan. Sudan as the other African countries allocated only a small percentage of its GDP for the STI. Before 2000s, the rate of spending on R&D in Sudan as a percentage of GDP was only 0.04%. In 2006, the share increased to 0.1%, which fell behind the average rate of the World and Arab countries, which spent on R&D as a percentage of GDP about 2.3% and 0.6%, respectively (Nour, 2012). Based on the Sudan Presidential Initiative for STI, which was proposed to UNESCO in 2009, issuing legislation required increasing spending on R&D to 0.5% of GDP in 2017-2019 and then up to 1% of GDP by 2020. This has not been achieved.

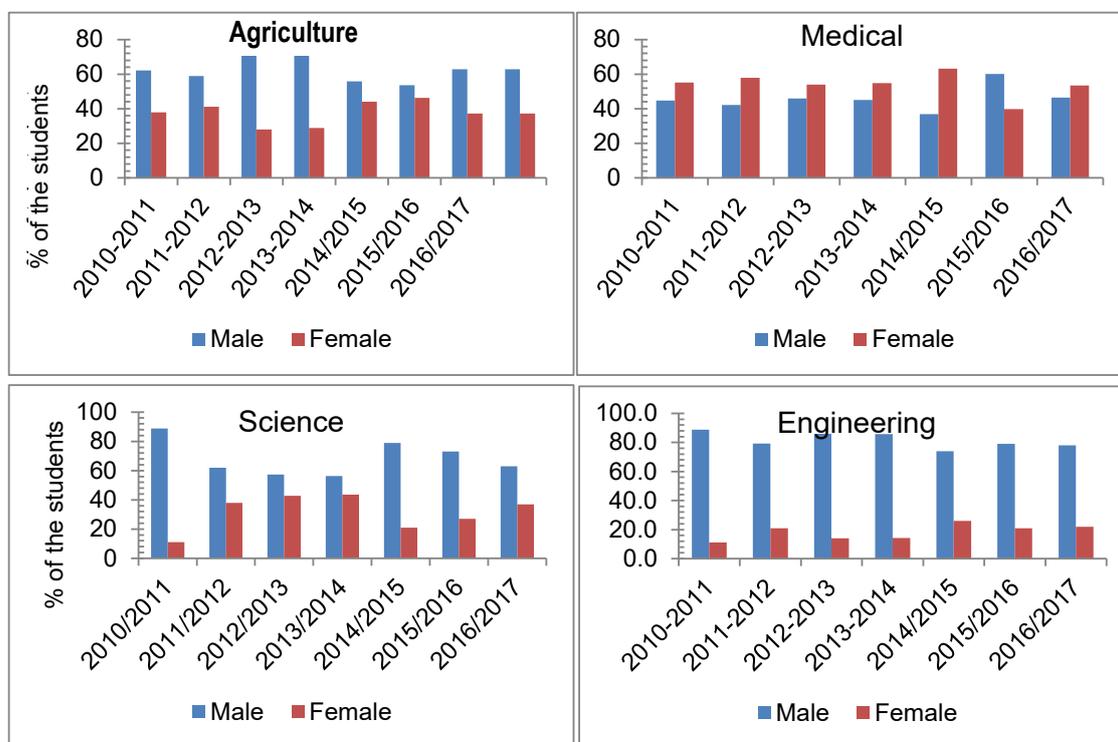


Figure 2. Percentage of female and male students at the doctorate level in agriculture, medical, science and engineering faculties

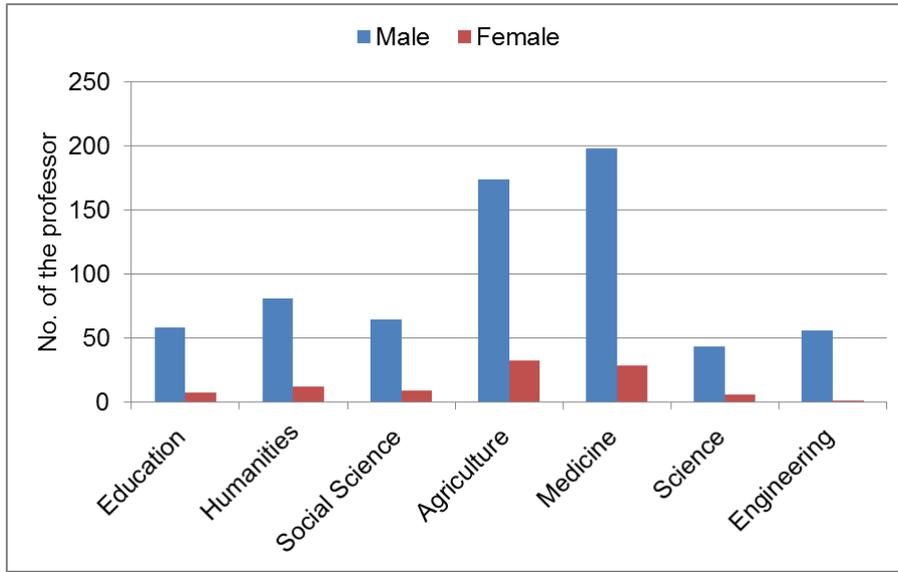


Figure 3. Number of female staff members in the various fields

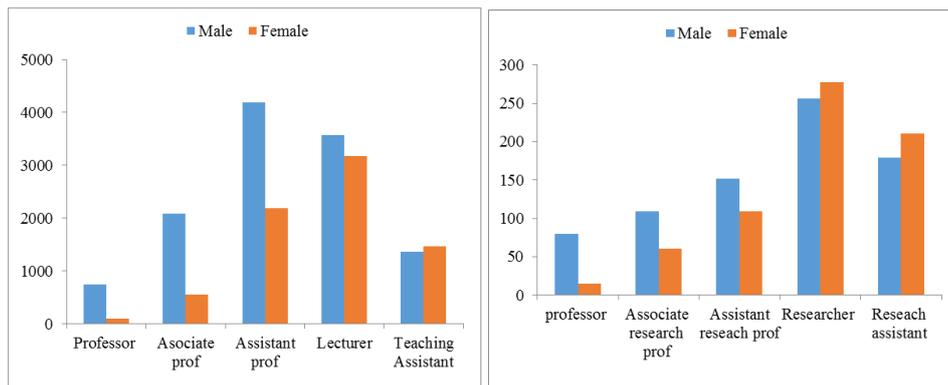


Figure 4. Number of female staff members in Sudanese universities and research institutes

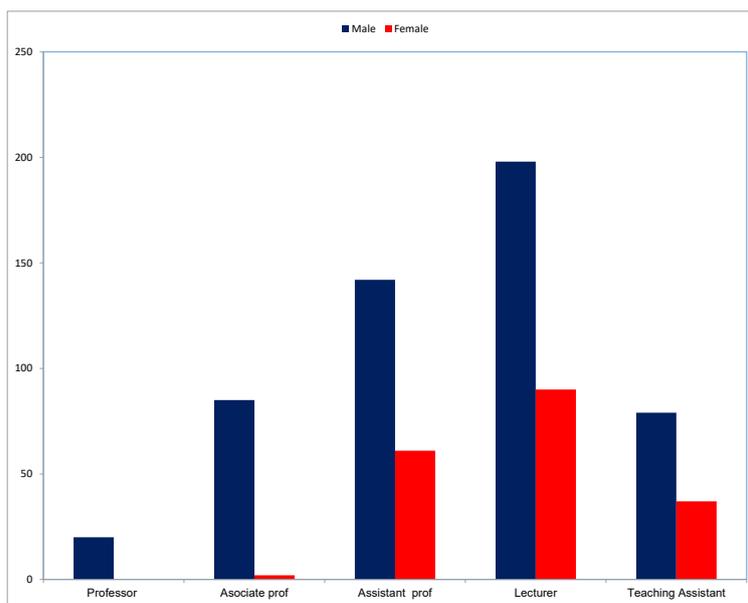


Figure 5. Number of female staff members in Kordofan University

The financial support to STI depends mainly on the public sector compared to a very low contribution of the private sector. According to Nour (2013) about 95% of total financial support to S&T is provided by government, mainly from MOHE and Ministry of Finance for some research institutes, compared to a very low contribution of the private sector in Sudan (only 5% of total financial support to S&T). Nowadays there are new policies for partnership with the private sector by using the infrastructure in some industries for some STI initiatives. The impressive growth in communication and information technology sector is considered a great lever for STI implementation.

As an indicator of research activities in universities, the MOHE started funding a large number of research projects for university staff members, and since 2004, the amount of fund released from MOHE to universities increased from 2.3 million SDG in 2009 (920 thousand US\$) to 250 million SDG (six millions US\$) in 2019. The number of projects varies depending on funds availabilities to MOHE from the Government and the quality of the projects submitted to MOHE (Figures 6 and 7). This

funding supported the research work of many staff members and resulted in some useful technological packages. The Government expenditure (GOVERD) on R&D in Sudan compared with other African countries is relatively low, where for example, countries like South Africa and Egypt spent more than 1\$ billion on R&D performed by public institutions (Cloete and Barley, 2011; Bunting and Cloete, 2014). The proportion of GOVERD as a percentage of GDP in Sudan is about 0.02% in 2019 which is far below the share suggested by Sudan Presidential Initiative for STI. This is low compared to other African countries. According to AIOIII (2019) the GOVERD for the Republic of Tanzania, Egypt and South Africa was 0.27%, 0.26% and 0.16%, respectively. The low contribution of the private sector in R&D expenditure might be due to the fact that the size of the business sectors in Sudan is small, which may not have enough financial resources to invest in R&D activities. It could also be due to the mind-set of the businessmen in Sudan who are not motivated to invest in research, and the low awareness of the role of R&D because the business sector is looking for short-term profit.

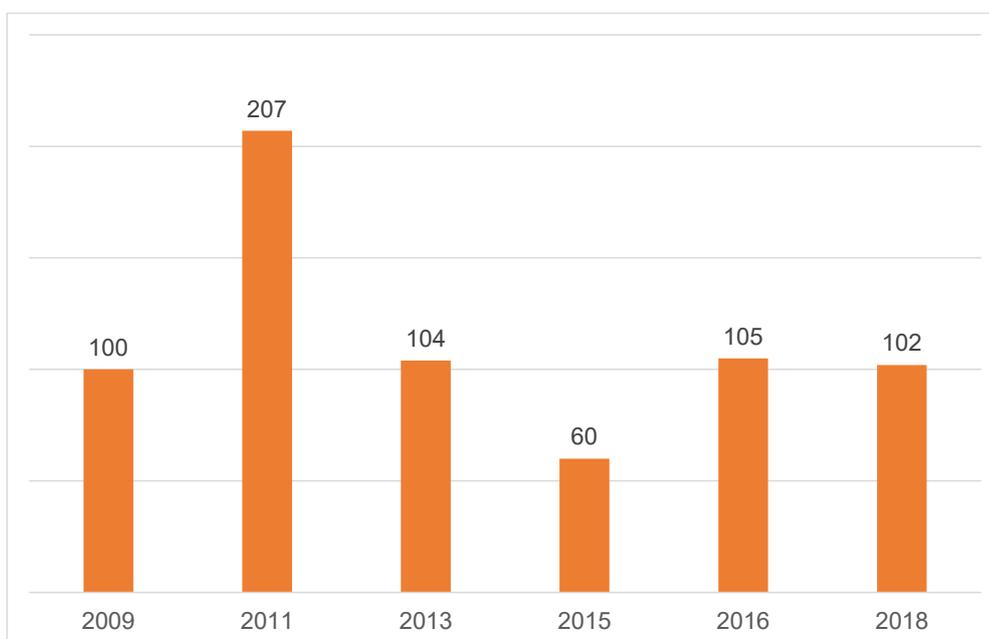


Figure 6. Number of research projects funded by Sudan Ministry of Higher Education and Scientific Research

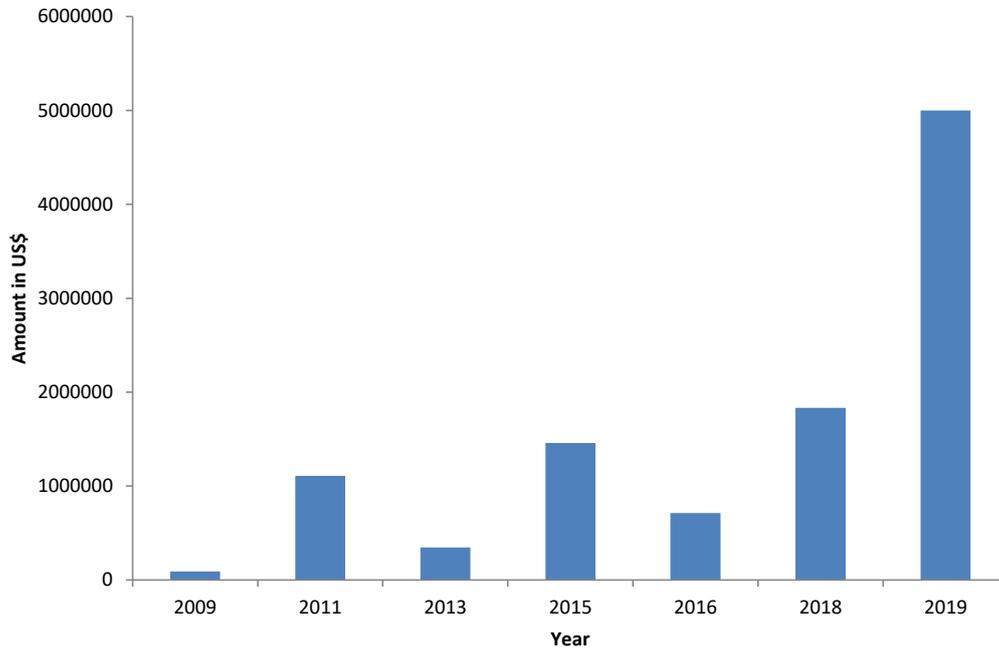


Figure 7. Funds released from MOHE to universities during 2009 to 2019 (in US\$)

Data presented in Table 3 show that 432 research projects were funded by MOHE during 2017-2018, of which only 65 projects were led by female researchers which represent only 15% of the total number. This indicates that the number of research grants obtained by female researchers is very low compared to the male researchers. This is mainly due to the fact that the criteria for application and awards of the grants require that the team leaders must be full professors or associate professors. As shown in Figure 5 there are few female professors and associate professors in research institutes and universities.

Supporting bodies for STI in Sudan. From the last decade many non-profit organizations were established to enhance and promote the STI system in Sudan. Some of these are highlighted below.

Sudanese Researchers Initiative (SRI). Founded in 2009, the main aim of the group is to establish a hub for the Sudanese researchers in a web-based platform, to motivate the Sudanese folks to share knowledge and to be involved

in R&D. This platform helps young and junior researchers to discuss their ideas openly. The SRI is a research community oriented initiative; it has about 92,403 researchers from different disciplines and various backgrounds. It is a forum and pool for innovative ideas, publications, seminars, awareness and other related topics (<http://www.saec.gov.sd>).

Incubators. Incubators constitute a vital component in STI schemes, aiming to support technology-based and innovation-oriented entrepreneurs. They also provide a flexible environment that helps and makes sure the business will survive and be protected, and offer many services such as workspace (on preferential and flexible terms), shared facilities, management training and a range of business support services. Being one of the government initiatives for STI, Sudan University of Science and Technology (SUST) has six incubators. Also Africa City for Technology has nine incubators. the main ones being: Leather Incubator; Cement Incubator; Poultry Incubator; Goat Production; Furniture Incubator; Oil Seeds Processing ; and Solar Energy.

Table 3. Amount of funds released from MOHE during 2017 - 2018 for male and female researchers

Field	Male		Female	
	Number of projects	Amount of fund (SDG)	Number of projects	Amount of fund (SDG)
Medical Sciences	93	23,345	13 (12%)	3,468
Agriculture Sciences	134	34,921	26 (16%)	5,600
Sciences	56	12,346	15 (21%)	4,023
Engineering	84	22,067	11 (12%)	3,492

STEM Girls' Clubs project. For enhancing the gender participation in STI, UNESCO ISESCO Chair for Woman in Science and Technology at Sudan University for Science and Technology launched STEM Girls Club in November 2018, with the objectives to encourage students to join science courses, awareness-raising that helps students to choose the science courses, bridging the gap in curriculum and courses, encourage students to follow technological developments, encourage discovery and innovation, contribute to the development of scientific research, and create partnerships between educational institutions.

Sudanese Women in Science Organization (SWSO). Started in 2013 as an arm of Organization for Women in Science for Developing World, its objectives are to support capacity building programs, community development programs, awareness campaigns, and establish central laboratories.

Innovation and Entrepreneurship Community (IEC). Started as an arm of IEEE Sudan subsection, which was known as IEEE Sudan entrepreneurship Centre (ISEC), IEC was launched in April 2013, with an objective to

support the entrepreneurial activities in Sudan.

Gender and Scientific performance in Sudan.

In this section, the STI output indicator is measured using scientific performance (in terms of publications and direct research output that has direct impact on economic growth of the country) and number of patents.

Scientific performance. There are many limitations concerning the data availability that address the scientific publications in Sudan, specially locally published research papers and articles. This could be attributed to the fact that most of Sudanese universities and research institutions lack electronic journals. Table 4 shows the publication outputs of some research institutions during the period from 2015 to 2018 that published in peer reviewed journals available at Scimago.com and Pubmed.com. Currently in Sudan, the output 0.03, reflects the low number of publications per researcher per year compared to the international rate of 2 papers for each researcher.

The success of R&D findings that contributes to development and economic growth of the country is used for measuring the impact of

Table 4. Number of Scientific Publications 2015-2018

Field	No of research papers
Agriculture	2380
Science	2300
Engineering	1253
Medicine	3669

*Scimago.com, Pubmed.com

STI output. During the last decades, there were successful applications of research results and technology in Sudan, which include the following: a) success in cultivation of wheat south of latitude 15°N by breeding heat-tolerant varieties, b) reduction of Belharziasis in the Gezira Scheme from 80% to 20% by applying appropriate control methods, based on research strategies and protocols at Blue Nile National Institute for Communicable Diseases, University of Gezira, c) production of new animal vaccines by the Faculty of Veterinary Medicine, University of Khartoum, and d) treatment of Hepatitis and cancer using camel milk and urine at University of Gezira. Besides the above mentioned outputs, there are many research findings produced by universities and research institutes still in the shelves and libraries which need to be applied at a large scale to maximize the benefits from research to the country's development.

Number of patents. Patents number can only be meaningful, if there is adequate knowledge of the criteria and methodologies used to register them. The patents reflect the inventive performance of a country (IPO, 2019). Before 2005, the number of patents registered in the Registrar of Intellectual Property in Sudan was only 12. This number increased to 426 by the end of 2013, which is still very low compared with other countries in Africa, e.g. there are 3694 patents in South Africa during the same period. This low number of registered patents is probably because Sudan has insufficient science and technology infrastructure and only 0.01% of GDP is spent on R&D during the period before 2005. There is however an increase in the

number of patents during the period 2013-2018 (Table 5). This is largely due to the increase in the fund received from MOHE (25 folds during the last five years) and also the share of R&D to GDP increased. The contribution of female researchers with registered patents is very low compared with that of male researchers (Figure 8).

Future perspective on gender participation in STI in Sudan. The various Sudan Governments have been aware about the gender disparities in the HEI and STI system. The Ministry of Higher Education and Scientific Research and the HEIs also acknowledge the need to enhance participation of males and females in STEM courses and the need to put in action gender strategy for equity in higher education policy, bearing in mind that the Sudan constitution and academic regulations for higher education admission system give equal rights for both males and females in education. The MOHE may need to adopt some mechanisms to increase female participation in STEM programs like using quota system, providing incentives and scholarships for females to choose science and technology related subjects. In addition to revised recruitment policies at the Universities and research institutes, women working environments, including flexible work schedules that guarantee equal opportunity for retention and progression are needed. In some Sudanese universities, the vision and mission statements are developed to focus on STI goals, such as at Sudan University of Science and Technology (SUST), University of Medical Science and Technology (UMST), Future University, and University of Science and Technology (UST).

Table 5. Number of registered Patents in Sudan (2015- 2018)

Year	Male	Female	Total
2015	169	17	186
2016	159	19	178
2017	176	33	209
2018	116	14	130

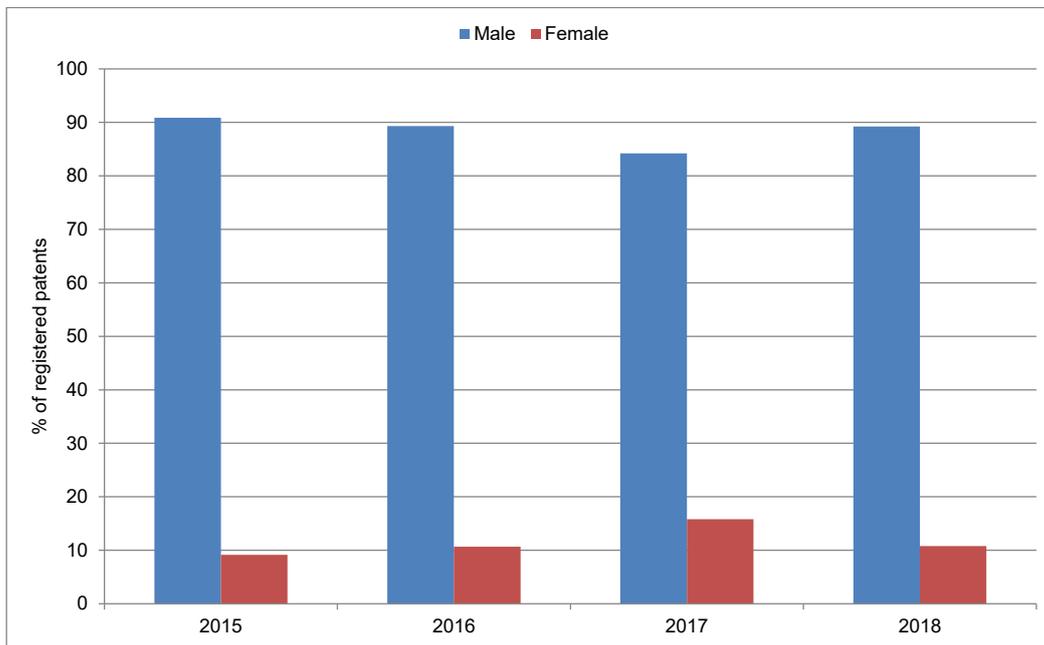


Figure 8. Share of females in registered patents

Also University of Gezira and University of Khartoum have Scientific Research strategies but gender issues are not considered. Most of the male students prefer to choose mathematics and engineering subjects because according to the Ministry of General Education, job markets are available making it easier to find work after graduation especially for mechanical and civil engineers. There are also opportunities for self-employment.

From the interviews with key actors and Ministry of General Education report there are arguments that the education system is not well equipped to facilitate the participation of both males and females, but more especially females in STEM programs. Most of the available STEM instructors are males specialised in mathematics and engineering subjects and are mostly in the boys' schools; about 74% of them are found in boys' schools and only in the big cities, while in rural areas the percentage decreased to less than 20%.

Some initiatives such as Sudanese Women in Science Organization, Sudanese Researchers

Initiative, STEM Girls' Clubs aiming at stimulating young researchers in general and women researchers in particular to participate in STI are encouraging students to join science courses. They undertake awareness-raising that helps students to choose the science courses, bridging the gap in curriculum and courses, encourage discovery and innovation, sharing knowledge and help young and junior researchers to discuss their ideas openly.

The Republic of Sudan has potential for establishing strong and concrete STI structures, which are currently distributed over many ministries that give the STI system a unique diversity. The Government distributes roles, responsibilities and hierarchy among STI organizations, but there is need to identify the steps and actions that lead to increased participation and enrolment of women in STI. These include, amongst others:

- a. Balance between working life, motherhood and other family obligations
- b. Stimulating women's self confidence
- c. Creation of a Network of Women Researchers
- d. Building the role model culture

e. Creating partnerships between educational institutions and global partners

CONCLUSIONS AND RECOMMENDATIONS

In Sudan, female students form the majority (55%) of enrolment at undergraduate level in higher education institutions and in some cases even reaching 70-80% like in Agriculture and Medical fields, while enrolment of girls in Science and Mathematics is less than 23%. However, the majority of these female graduates are unemployed. The women involvement in decision making roles in academia and industry is very low, with very few women scientists involved in leadership and their participation in research and development is also low.

In Sudan, there is no existence of STI national policy or framework in the Ministry of General Education and Ministry of Information and Communication Technology. However, the MOHE developed an STI framework “Policies and Strategies of Science, Technology and Innovation” but there is no mention of gender or gender equity as separate issues. The gender equity appeared in the framework of Ministry of Security and Social Development but there is no clear focus on STI issues. Therefore, efforts to ensure greater inclusion of women in the STI ecosystem in Sudan are highly needed and should be embedded in national and institutional frameworks. The number of females decreased significantly in high seniority levels. There were only 15 female professors out of 95 professors in research institutes. After the December revolution in 2018, the representation of women in STI high ranking positions increased to three Vice Chancellors, while the number of Deans increased to nine in AlNeelain University and eleven in Sudan University of Science and Technology. This positive development has been made possible as a result of the conditionality in the new constitution to ensure at least 40% female representation in government labour force as a general policy guideline.

The financial support to STI depends mainly on the public sector (financing from Government), compared to a very low contribution from the private sector. Nowadays, there are new policies for partnership with the private sector by using the infrastructure of industries for some STI initiatives. In Sudan, the gender participation in STI is not emphasized in policies and strategies of STI. However, there are some initiatives through non-governmental organizations to stimulate and enhance women participation in STI programs.

Arising from the above analysis, the following recommendations should be considered:

- Increase funding from public and private sector for the different research institutes and universities, including creating an Innovation Fund to be accessed competitively;
- Offer incentives and motivation for researchers with especial consideration for female researchers
- Creation of more favourable conditions for females and offering the necessary facilities and improvement of R&D culture.
- Increase availability of sufficient human resources and adequate research infrastructure
- Enhance technical competencies of human resources through capacity building training and curriculum reforms
- Offer incentives and motivation for females to join the STEM fields
- Improve management, coordination and networking between the related institutes including ministries
- Build the role model culture, mentoring and coaching for female students and researchers
- Create partnerships between Sudan educational institutions and related institutions in Africa and globally
- Establish education fund to train Sudan masters and PhD students in Sudanese and other African universities

- Establish initiative to build capacity in emerging areas related to digital technologies and data science
- Establish STI centres of excellence in Sudan

ACKNOWLEDGEMENT

This study was funded through ISDB support to Busitema University and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) through the TAGDev Project funded by the Mastercard Foundation.

STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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