African Journal of Rural Development, Vol. 5 (3): July-September 2020: pp.65-86. ISSN 2415-2838

Strengthening higher education capacity to promote gender inclusive participation in Science, Technology and Innovation

F. NAKAYIWA.,[1] M.M. ELHAG.,[2] L. SANTOS,[3] D. KIFLE[4] and C. TIZIKARA[5]
[1]Regional Universities Forum for Capacity Building in Agriculture, Plot 151/155 Garden Hill, Makerere University, P.O. Box 16811, Wandegeya, Kampala, Uganda
[2]University of Gezira, P.O. Box 20, WadMedani, Sudan
[3]Faculty of Agronomy and Forestry Engineering, Eduardo Mondlane University, Av. Julius Nyerere, Campus Universitário 3453, P.O. Box 257, Maputo, Mozambique
[4]Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia
[5]Agrotiz Limited, P.O. Box 16409, Kampala, Uganda
Corresponding Author: f.nakayiwa@ruforum.org

ABSTRACT
Despite global Science, Technology and Innovation (ST&I) initiatives to ensure achievement of Sustainable Development Goal (SDG) number 5 on gender equality, and those geared towards supporting greater engagement of women especially in research for development, fewer women are still employed in the Science, Technology and Innovations (ST&I) sector. The Forum for African Women Vice Chancellors (FAWoVC) is exploring interventions to promote women in higher education, and ST&I. A baseline study of the ST&I ecosystem from four African countries, reveals that higher education is still skewed against ST&I. Female participation is still low and steeply declines at the graduate and academic leadership levels. In promoting female engagement, the policy framework at national and institutional level needs to target the overall education pipeline and create an environment that supports students in Science, Technology, Engineering and Maths (STEM) and females in the R&D employment sector.

Key words: Africa, gender, higher education, Science, Technology and Innovation

RÉSUMÉ
Malgré les initiatives mondiales de ST&I visant à assurer la réalisation de l'objectif de développement durable (ODD) numéro 5 sur l'égalité des sexes, et celles visant à soutenir un plus grand engagement des femmes, en particulier dans la recherche pour le développement, moins de femmes sont encore employées dans le secteur de la science, la technologie et les innovations (ST&I). Le Forum des femmes africaines rectrices (FAWoVC) explore des interventions pour promouvoir les femmes dans l'enseignement supérieur et en ST&I. Une étude de base de l'écosystème ST&I de quatre pays africains révèle que l'enseignement supérieur est toujours biaisé par rapport aux ST&I. La participation des femmes est encore faible et diminue fortement aux niveaux de gradués et la direction universitaire. En promouvant l'engagement des femmes, le cadre politique aux niveaux national et institutionnel doit cibler le pipeline global de l'éducation et créer un environnement qui soutient les étudiants en sciences, technologie, ingénierie et mathématiques (STEM) et les femmes dans le secteur de l'emploi en R&D.

Mots clés: Afrique, genre, enseignement supérieur, science, technologie et innovation

Cite as: Nakayiwa, F., Elhag, M.M., Santos, L., Kifle, D. and Tizikara, C. 2020. Strengthening Higher Education capacity to promote gender inclusive participation in Science, Technology and Innovation. *African Journal of Rural Development* 5 (3): 65-86.

Received: 10 June 2020
Accepted: 20 June 2020
Published: 30 September 2020

INTRODUCTION

Promoting gender equality, Science, Technology and Innovation (ST&I) policies to benefit both men and women are acknowledged as fundamental to reducing poverty and ensuring equitable development (United Nations, 2019). Indeed a UN Women discussion paper contends that gender equality and poverty are intrinsically linked (Nieuwenhuis *et al*., 2018). The World Economic Forum Gender Report (WEF, 2018) further contends that female participation does not only provide talent to tackle the challenges facing humanity, but has other equity and social security benefits such as well-paid careers that boost the economic security of women, and provides the foundation for greater social and political influence. Despite the several global ST&I initiatives to ensure achievement of Sustainable Development Goal (SDG) number 5 on gender equality, and those geared towards supporting greater engagement of women especially in research for development, fewer women are still employed in the ST&I sector. Participation and employment of women in higher education, and ST&I remained low (UN, 2019).

Sub-Saharan Africa (SSA) at approximately 31% female in the key ST&I areas is no exception to under representation against the world average of 29.3% (UNESCO, 2019). In many African countries, university departments and research institutes are often led by men who also occupy key leadership positions of responsibility. Within the R&D sector, women scientists experience challenging work environments, which are compounded by persistent gender biases, and stereotypes entrenched within the research and academic institutions. In addition, several institutions are yet to adopt programmes that provide professional support to attract, recruit and retain women scientists. This coupled with the absence of mentoring programmes and undefined career path, inhibit female participation in ST&I (Muthumbi, 2015).

The majority of African countries recognize the need to increase female participation in higher education and ST&I. However, the actions taken at national, sub regional and continental levels to promote women in higher education, science and technology are yet to deliver on this promise. The East African Community (EAC), the Southern Africa Development Community (SADC) and the Economic Community for West African States (ECOWAS) for example have all come up with initiatives to promote women in ST&I. In most cases, they have adopted Gender and ST&I frameworks to promote gender mainstreaming and equity, entrepreneurship training, and education. Innovative solutions and initiatives such as the continental *African Union Kwame Nkrumah Regional Award for Women Scientists* geared towards creating awareness and improving women participation in ST&I with a view to promoting equitable development and livelihoods have been developed.

Through the Forum for African Women Vice Chancellors (FAWoVC) support from the Islamic Development Bank to develop initiatives to increase participation of women in ST&I in Africa, country focused Gender ST&I studies were commissioned in Ethiopia, Mozambique, Sudan and Uganda. The FAWoVC is an umbrella group of female university leaders in Africa that was created in 2016 to spearhead gender responsive training in higher education institutions and to increase the enrolment of female students in Science, Technology Engineering and Mathematics (STEM), as well as galvanize women to take up leadership positions in the academe. The FAWoVC establishment recognized that mainstreaming gender within higher education is of paramount importance for enhancing the performance of higher education institutions and enabling them to fulfil their mandates to train the next generation of talent that will drive the African continent forward. Women, STEM and education are key tenets of the global development agenda as espoused in the SDGs, and the African Union Agenda 2063.

The overall objective of the commissioned studies was to gain a scientifically based understanding of the status of ST&I in the four countries to guide future capacity development. The studies premised to establish the gaps that have been created because of inadequate focus on gender and ST&I and to identify the gender-based capacity gaps, challenges, opportunities and future prospects. The studies outlined the key actors at country level, the link between higher education to the national ST&I ecosystem and explored strategies to increase participation of women in ST&I.

Through literature review, compilation of secondary data, documents analysis and semi-structured interview, a team of country-based experts undertook gender focused assessment of higher education systems, with specific emphasis on current gaps to support ST&I in national agricultural innovation systems. Data on female enrolments, graduation and academic staff in the higher education institutions were analysed, providing an overview of female participation in ST&I. Specific attention was paid to case studies of universities in the countries of focus.

The ST&I Ecosystem Actors in Ethiopia, Mozambique, Sudan and Uganda

Although most African countries have ST&I policies and strategies, their capacity to implement them remains low. Indeed ST&I institutions remains underdeveloped and have not effectively deployed knowledge and technological innovations for socioeconomic growth (ACBF, 2017). The status largely reflects the inadequate staffing, skills, expertise, financial resources, infrastructural capabilities, and equipment in the ST&I institutions. Inadequate capacity and utilization of advances in ST&I prevents African countries from capturing the benefits of S&T, leading to missed opportunities, that are common place in other parts of the world (Watkins and Ehst, 2008).

Sound innovation ecosystems must balance start-ups, scale-ups, and mature firms' (Cornell University, INSEAD *et al*., 2020). The ST&I ecosystems of the countries in the study do not clearly articulate this trajectory, which is an indication of the policy direction and status of innovation at national level. For Ethiopia, Mozambique and Uganda that are ranked by the global innovation index, their score is beyond 100 out of the 129 ranked countries in 2019 (Cornell University, INSEAD *et al*., 2019) with a decline registered in 2020 out of the 131 countries ranked (Cornell University, INSEAD *et al*., 2020).

All countries in this study have complex ST&I ecosystems that would make it difficult to operationalize the ST&I agenda at national level. A multiplicity of players ranging from research institutes, universities, technology transfer agencies, chambers of commerce and industry, to financing institutions, investors, government departments, regulatory agencies as well as Ministries of Agriculture, Finance and ST&I where applications have a role (see Table 1). Apart from Mozambique and Ethiopia, these ecosystems do not have special focus on gender as a key attribute and driver for ST&I.

Uganda and Ethiopia have independent Ministries of Technology and Innovation, to drive the ST&I agenda in their respective countries, while the Ministries responsible for higher education have the mandate in Sudan and Mozambique. Ministry of Science and Higher Education in Ethiopia is mandated to manage higher education and Technical and Vocational Education and Training (TVET) institutions. In addition, largely due to R&D funding process, the ST&I agenda and indeed the ecosystem is driven by the international development agencies. In all four FAWoVC study countries, the General Expenditure on Research and Development (GERD) at less than 0.6% of GDP is below the recommended average of 1%, a role taken on by external resources and the private sector. The sections below provide an overview of the ST&I ecosystem by country.

Table 1. Key actors in the ST&I ecosystem in study countries

Key Actors	Country			
	Sudan	**Uganda**	**Mozambique**	**Ethiopia**
Coordinating Entity	Ministry of Higher Education	Ministry of Science Technology and Innovation	Ministry of Science, Technology, Higher and Technical-Professional Education	Ministry of Science and Higher Education
Inclusion/Gender Focus	×	×	√	√
Academic Institutions	√	√	√	√
Human Resource Development	×	√	√	√
Private Sector	√	√	×	×
Research Centres and Institutes	√	√	√	√
Industry Sector	√	√	√	√
Technology transfer / Parks and Incubation hubs	×	√	×	√
External/imported technology and FDI	×	√	√	×
Financing and Incentive Scheme	×	√	×	√
Quality Infrastructure	×	×	×	√
Government Ministries	ICT	×	Ministry of Mineral Resources and Energy	Science and Higher Education
	Agriculture		Technology, Higher and Vocational Education	Education
	Industry		Education and Human Development	Innovation and Technology

Sudan

The ST&I ecosystem in Sudan has evolved over the years from 1902 when the first R&D laboratory (The Welcome laboratory) and the Agricultural Research Station were established in 1904. The National Council for Research (NCR) was established in the 1970 as a governmental body responsible for formulating policies and plans for coordinating national science and technology efforts. The NCR ceded responsibility to the Council of Higher Education and Scientific Research in 1991-1992 and later to the Ministry of Science and Technology (MOST) that was abolished in 2015.

The current ST&I configuration is distributed across four key players namely, i) The Agricultural Research Corporation and Livestock Research Corporation at the Ministry of Agriculture and Livestock. ii) The National Information Centre at the Ministry of Information and Communication Technology, iii) The National Research Centre and Universities at the Ministry of Higher Education (MOHE), and iv) The Industrial Research and Consultation Centre at the Ministry of Industry. This in addition to private sector and other players (see Figure 1). The complexity of the science ecosystem notwithstanding, the number of players is an indication of fragmentation that affects the central coordination and harmonisation of ST&I initiatives in the country. Sudan is not ranked by the Global Innovation Index that provides a detailed metrics about the innovation performance of countries and economies around the world.

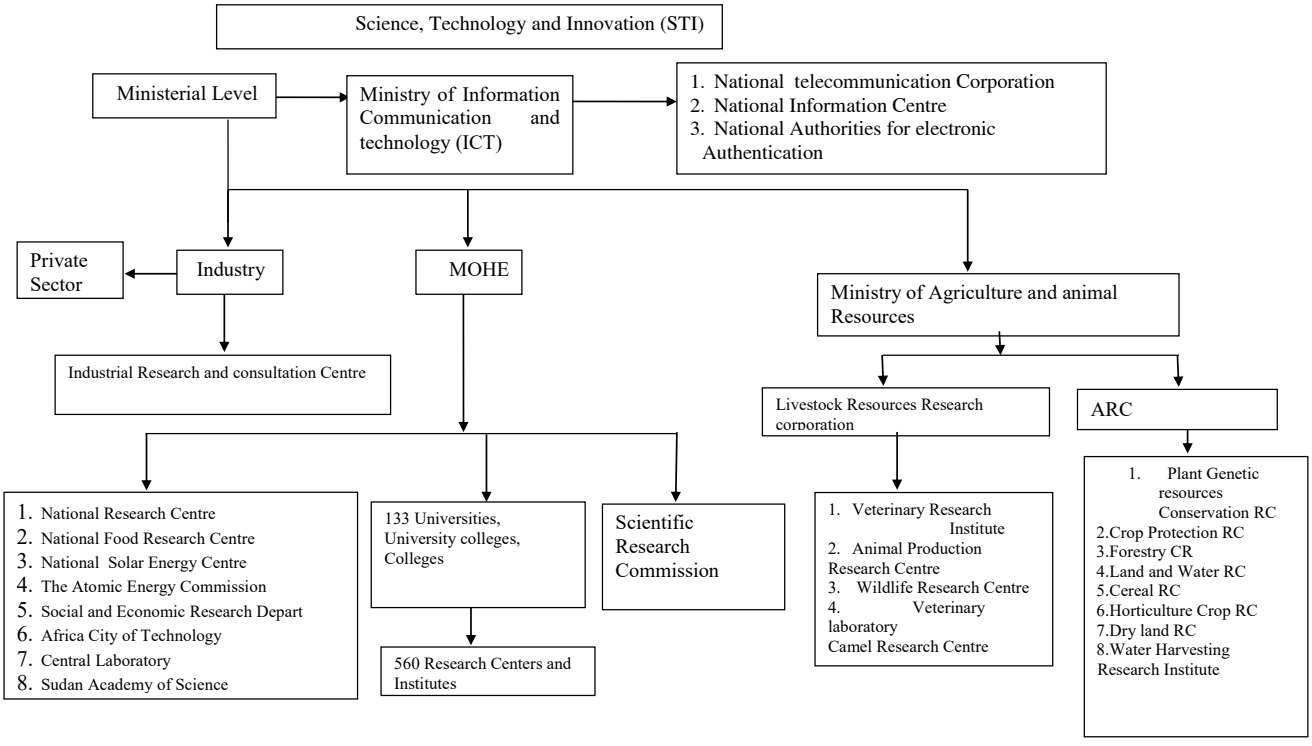

Figure 1. Sudan Science, Technology and Innovation ecosystem

Uganda

In Uganda, similar to Sudan, the complexity and harmonization of the ST&I ecosystem has evolved over time, from the National Research Council (NRC) in established in 1970 to the Uganda National Council for Science and Technology (UNCST) established by Act of Parliament in 1990. A Ministry of Education, Sports, Science and Technology to oversee ST&I was created operating in parallel with the UNCST which was superintended by the Ministry of Finance, Planning and Economic Development. In 2016 an independent Ministry of Science, Technology and Innovation (MoSTI) was created with the UNCST as an agency under the new Ministry. The MoSTI has developed the ST&I policy that guides the ecosystem and incorporates other ministries, higher education institutions and the private sector while recognizing the role of foreign direct investment (Figure 2). In terms of innovation, Uganda ranked 102 in the Global Innovation Index of 2019 sliding to 114 in 2020 (Cornell University, INSEAD *et al.*, 2019; Cornell University, INSEAD *et al.*, 2020).

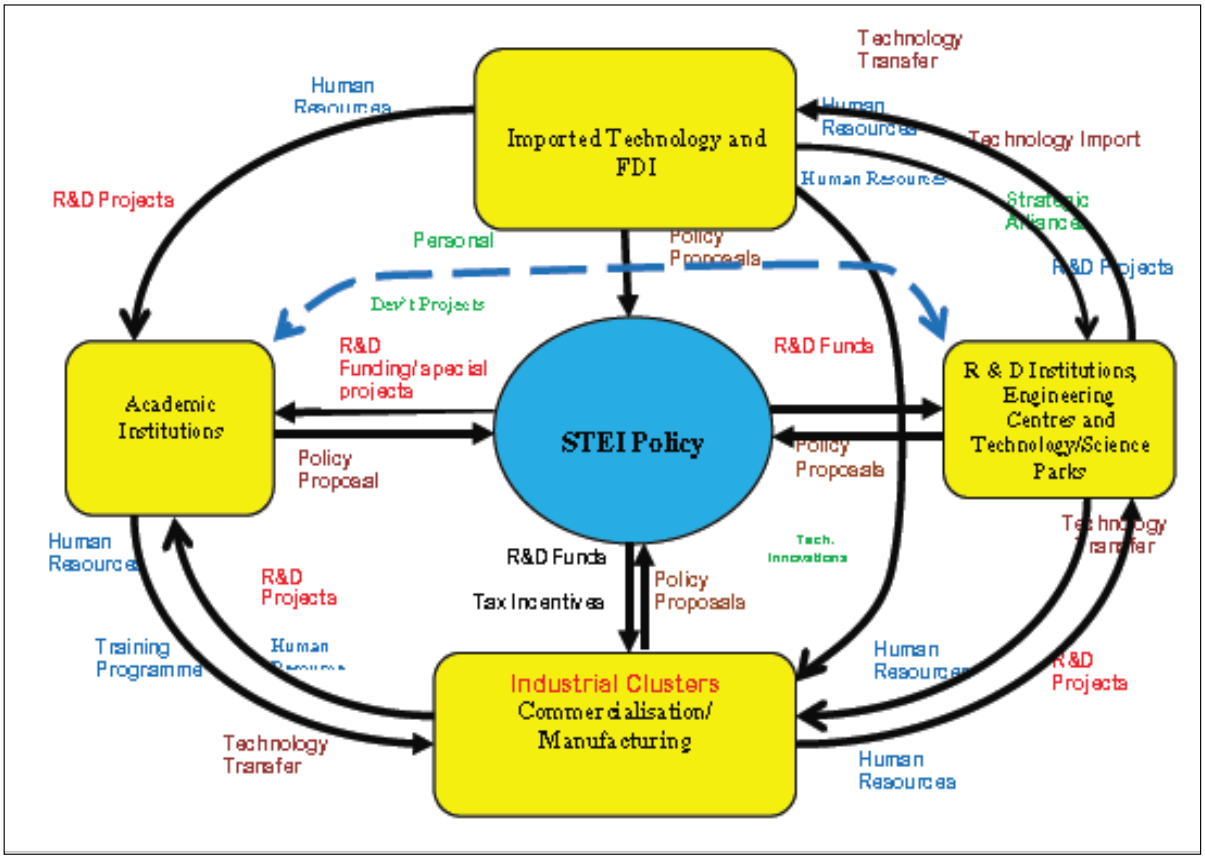

Figure 2. ST&I ecosystem in Uganda

Mozambique

The Mozambique ST&I ecosystem is equally complex and has evolved from 2000, when the first Ministry of Higher Education, Science and Technology was established with the aim of development of a skilled workforce, expansion and equity of access to quality higher education, development of technologies and identification of Mozambican resources and products that could serve as development factors. In the last 20 years, this Ministry has experienced different formats. From 2005 to 2015, the Ministry changed its focus to only Science and Technology and was renamed Ministry of Science and Technology (MCT) to coordinate the implementation of the S&T strategy with a separate Ministry responsible for Education. Since 2015, MCT has been reconfigured by re-integrating higher education as well as technical and vocational education, and renamed Ministry of Science, Technology, Higher and Technical-Professional Education (MCTESTP). These iterations similar to Uganda and Sudan signify fragmentation and a multiplicity of ST&I actors in the country that require clear thought processes for harmonization. A schematic representation of the Mozambique ST& I ecosystem is given in Figure 3. Mozambique was ranked 119 in 2019 and 124 in 2020 by the Global Innovation Index, (Cornell University, INSEAD *et al.*, 2019; Cornell University, INSEAD *et al.*, 2020)

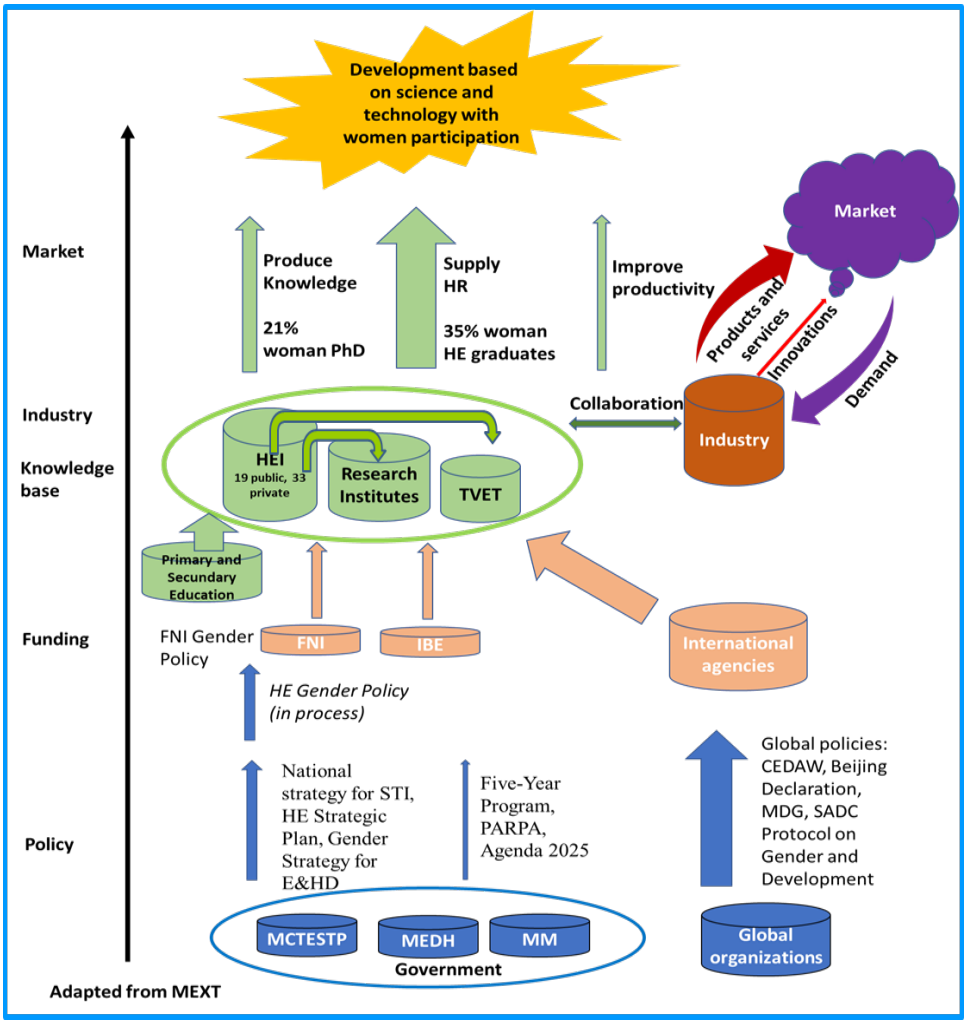

Figure 3. Mozambique Science Ecosystem

Ethiopia

Science, Technology and Innovations gained prominence in Ethiopia from 1975 with the establishment of the Ministry of Science and Technology. The primary aim at the time was to provide evidence-based recommendations for adopting and revising polices, strategies, laws and directives for the development of ST&I that support the realization of the country's development objectives, (Tesfa, 2015). Currently it is designated as the Ministry of Innovation and Technology (MoIT). The country applies ST&I as an instrument to achieve the long-term vision of the country to reach middle-income status (Ministry of Education, 2015). Ethiopia developed its ST&I policy in 2012 with a vision of establishing the capabilities, which enable rapid learning, adaptation and utilization of effective foreign technologies by the year 2022/23 (Federal Democratic Republic of Ethiopia, 2012). Similar to other countries in the study, Ethiopia has a complex ST&I ecosystem (Figure 4). Ethiopia was ranked 119 in the Global Innovation Index of 2019 sliding to 127 in 2020 (Cornell University, INSEAD *et al*., 2019; Cornell University, INSEAD *et al*. 2020)

All countries acknowledge that academic institutions are key actors in the ST&I space as generators of knowledge. For Ethiopia, quality Infrastructure and inclusive innovation for sustainable development stand out. As such, one can deduce that gender and youth issues have been placed at the centre of the ST&I for sustainable development trajectory.

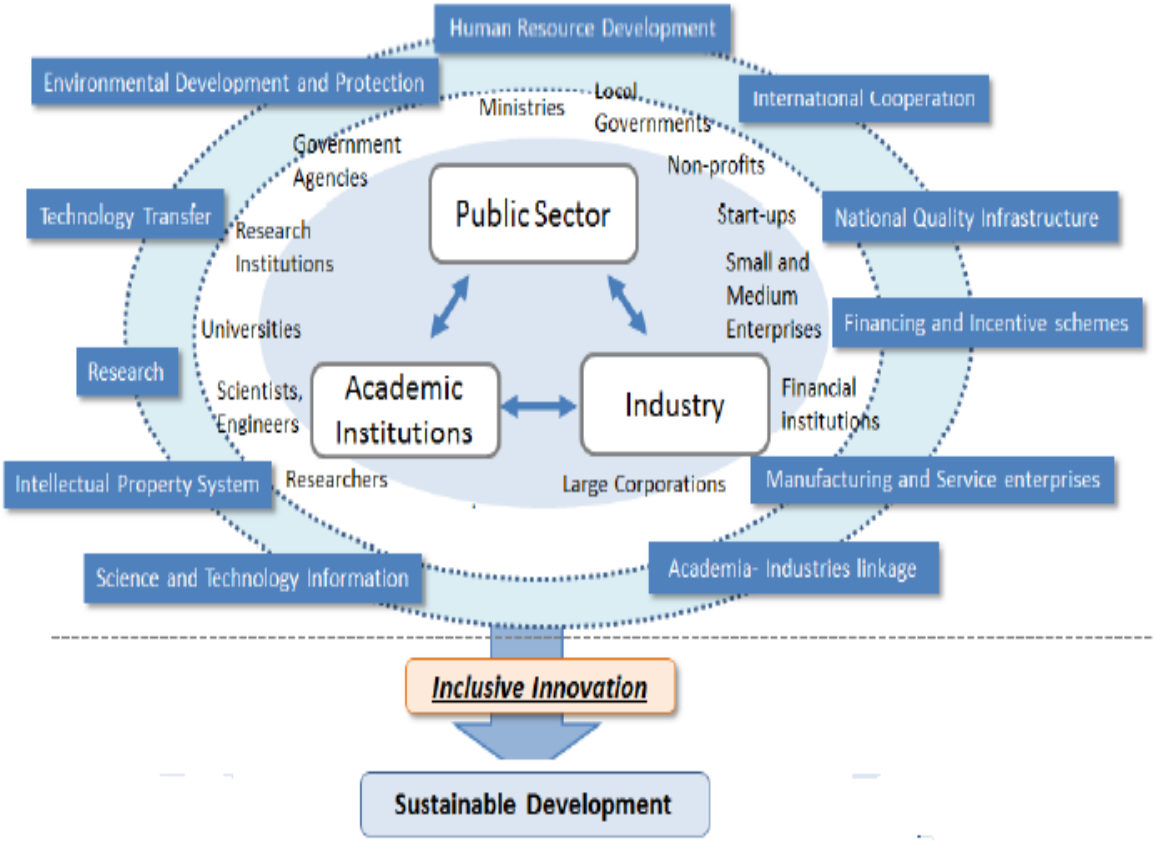

Figure 4. Key actors and policy issues in STI Ecosystem in Ethiopia (adopted from World Bank, 2016)

Participation and Access to Higher Education Science and Technology

Science, technology and innovation is critical for responding to the challenges of African agriculture and to elevate its performance and contribution towards economic development and poverty alleviation (Watkins and Ehst, 2008; ACBF, 2017). Universities have a key role to play in producing the next generation of the African workforce, including researchers/scientists, extension and advisory service practitioners, input dealers and other development practitioners that are expected to generate, translate, extend and share knowledge with rural farmers to increase agricultural productivity, agribusiness and incomes (ACBF, 2017). Trained human resources in a wide range of topics, aligned to the Science Agenda for African Agriculture, are central to stimulating science-based technology innovation. Research has shown that returns to investment in higher education are around 20%, and in Africa closer to 30%, and are higher than returns in both secondary and primary education (Montenegro and Patrinos, 2013; Borland *et al*., 2000).

Despite a higher proportion of women in sub-Saharan Africa (SSA), women are under-represented in key areas of ST&I and higher education. The UNESCO (2015) Science Report indicates very low representation of females in all science fields with 17.1% (natural sciences), 23.3% (engineering and technology), 30.6% (medical), 19.7% (agricultural sciences) and 27% (social sciences). The gender gap in ST&I is apparent in academic and research institutions at student, staff and leadership position level.

In Uganda, while affirmative action has increased female enrolment in higher education, participation is STEM programs at 37% is still limited (NCHE 2019). At Makerere University, the country's largest and premier university in Uganda, only 28% of academic and research positions are occupied by women, with similar situations exhibited in all 46 universities (NCHE, 2013). With only four female Vice Chancellors, the gender equity status in Uganda can benefit from mentorship and grooming of female academic leaders. Overall, ST&I remains below 30% of total enrolment over the years (NCHE, 2019), Figure 5.

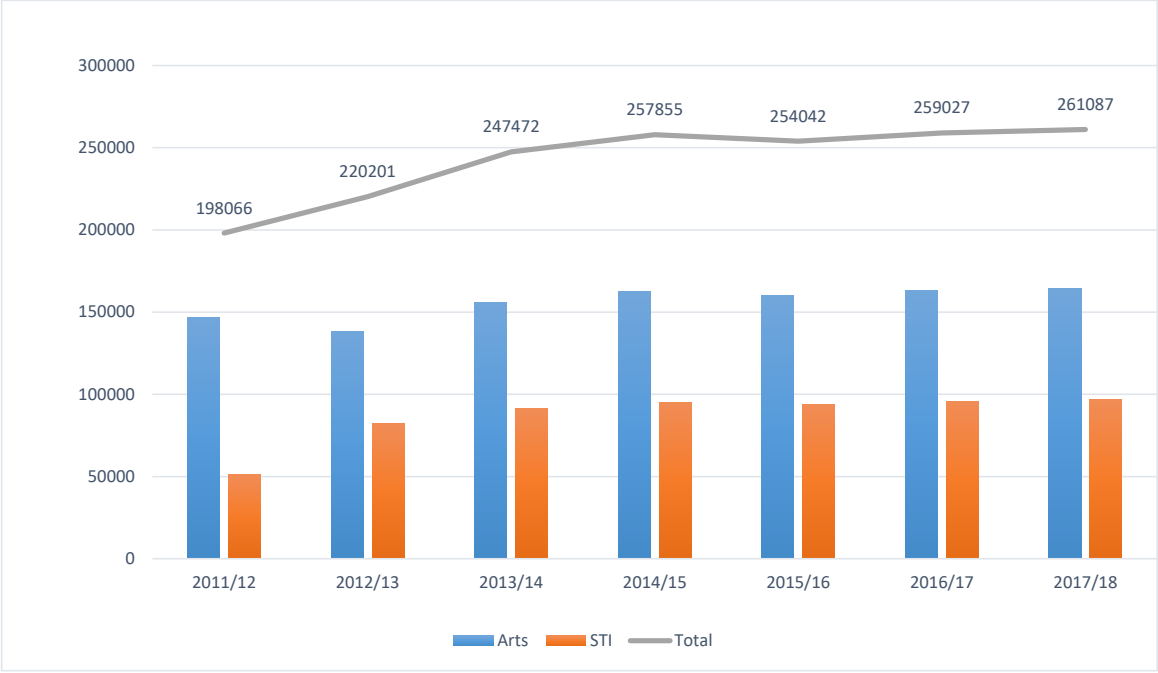

Figure 5. Students enrolment trend in Uganda-(NCHE, 2019)

For Busitema University as a case in the current study, despite a strong commitment to gender parity in the administration, female staffing and student enrolment, is still elusive. There are only five (25%) female members of the University Council and 23.8% of the academic staff with no females at professor or associate professor levels and only one (1) female Senior Lecturer (representing 6.7%). Only one (14.3%) of the Heads of the seven academic units is female. However, the university had the opportunity of having the first female Vice Chancellor of the nine public universities in Uganda.

With respect to enrolment, female participation in 2018/2019 stood at (27.1%) for courses in engineering and science and education (27.8%), compared to health sciences (38.9%), agriculture (31.4%), natural resources management (31.8%) and business (37.1%). The proportion of females enrolling for postgraduate study is equally low at (25.2%) with noticeable differences for medicine (33.3%) and business administration (40.7%) compared to irrigation and drainage engineering (7.1%), industrial mathematics (11.1%) and computer forensics (7.7%)[1] .

In Mozambique, apart from medical sciences where women make up 53% of scientists, women lag behind in the rest of the fields. For both Uganda and Mozambique (focus countries for the FAWoVC proposed intervention), the numbers of female students at higher education level have remained low compared to the male counterparts (Figure 6).

Across the education levels, the percentage of female PhD researchers in Mozambique is lower than the ones with MSc and with BSc, confirming the 'leaky pipe' of lost talent for females and suggesting that males are more likely to advance their academic qualifications than females. The Ministry of Science data indicatethat by 2016, out of the 7,030 researchers in the country only 28.9% were female. Researchers with PhDs accounted for 14.8% out of which 11.3% were male and 3.5% female, respectively. The number of male researchers at all levels is more than two times greater than female researchers. Similarly, women in Mozambique are under represented in the academic staff of higher education institutions (António and Hunguana, 2013).

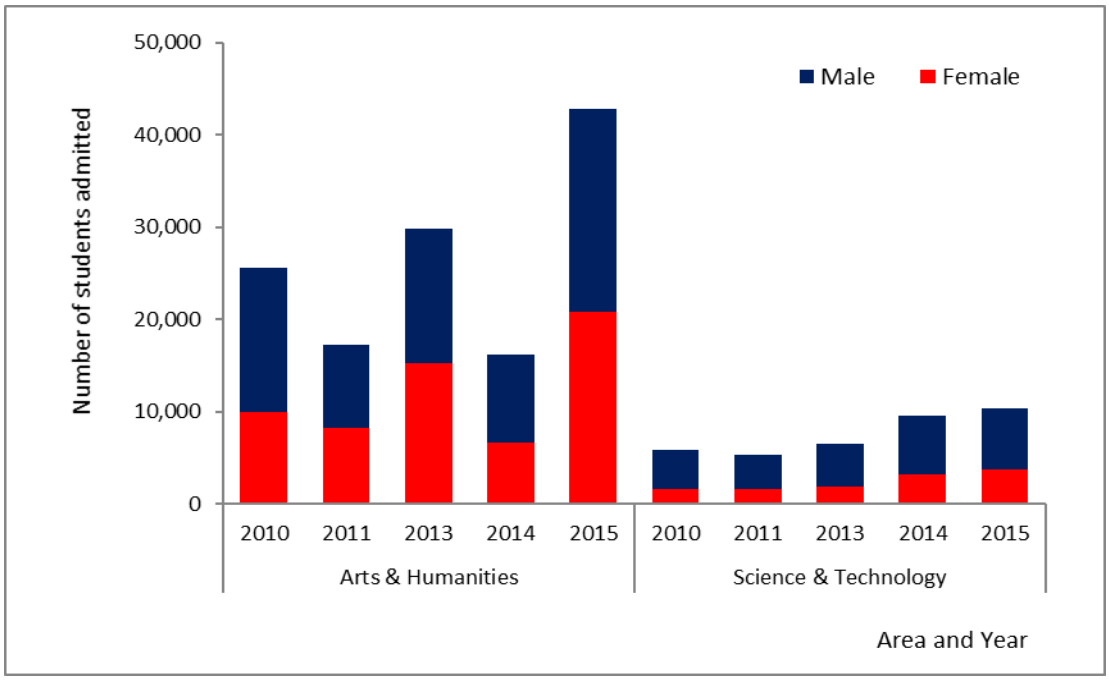

Figure 6. Students enrolment trend in Mozambique

[1]Computed from university records

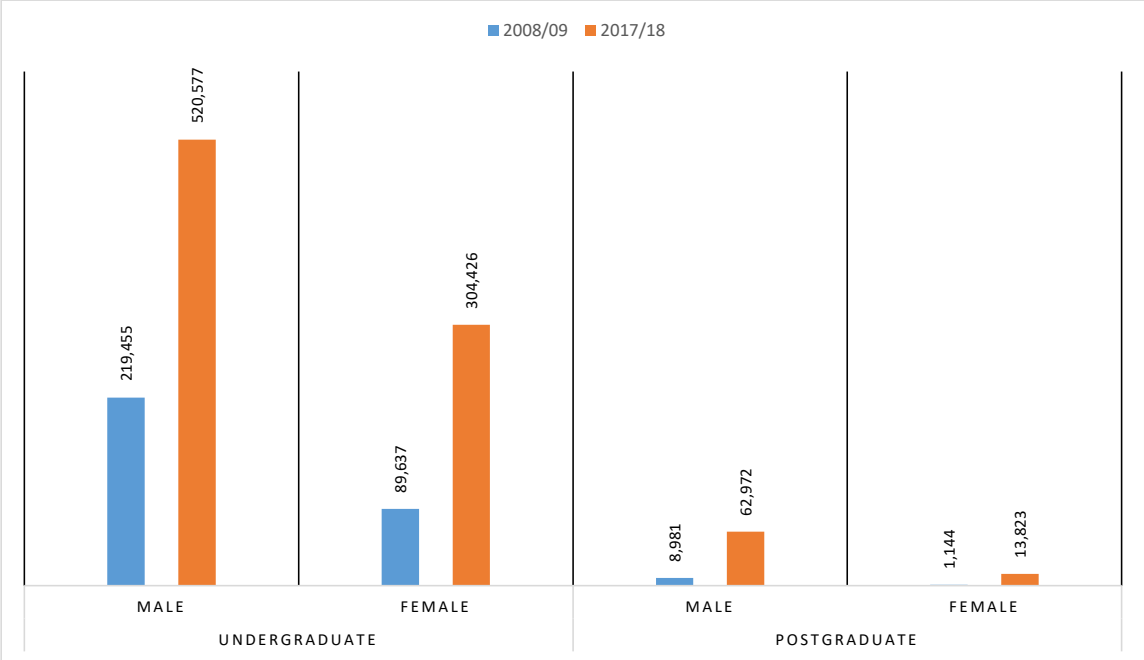

Figure 7. Students enrolment trend in Ethiopia 2008/09-2017/18

In Ethiopia, similar to other countries in sub-Saharan Africa, higher education enrolment has improved over the past three decades and the proportion of undergraduate female students increased from 29% in 2008/09 to 36.9% in 2017/18 academic year. The percentage of postgraduate students increased from 11.3% in 2008/09 to 18% in 2017/18 academic year (Figure 7).

The Government 70:30 policy in favour of STEM outlined in six discipline specific bands for participation in higher education in public universities has increased participation in ST&I. Unlike other countries in the study, Band 1, Engineering and Technology has the highest number of undergraduate students enrolled in Ethiopia. Band 6, Social Science and Humanities and Band 5, Business and Economics followed this. Band 2 Natural and Computational Sciences, Band 3 Medicine and Health Sciences and Band 4 Agricultural and Life Sciences took the 4th , 5th and 6th rank, respectively.

Combined, while the ST&I bands (1-4) have more students than the humanities at 63% for males and 57% for females, they were yet to reach the target ratio of 70% across the years 2014/15 – 2018/19 (Figure 8). Analysed further, the female percentage in the humanities is higher than in the sciences compared to the male counterparts. The composition was 148,966 (74%) male and 53,656 (26%) female in Band 1, Engineering and Technology for academic year 2018/19, Band 6, Humanities and Social Sciences at 100,701 (61%) male and 65,664 (39%) female. Band 3, Agricultural and Life Sciences had parity at 50% for both male and female in the same academic year. The adopted 70:30 policy for increasing participation in ST&I while good may have disadvantaged females from participation in higher education in Ethiopia (Ministry of Education, 2016; Ministry of Education, 2018; Ministry of Science and Higher Education, 2020).

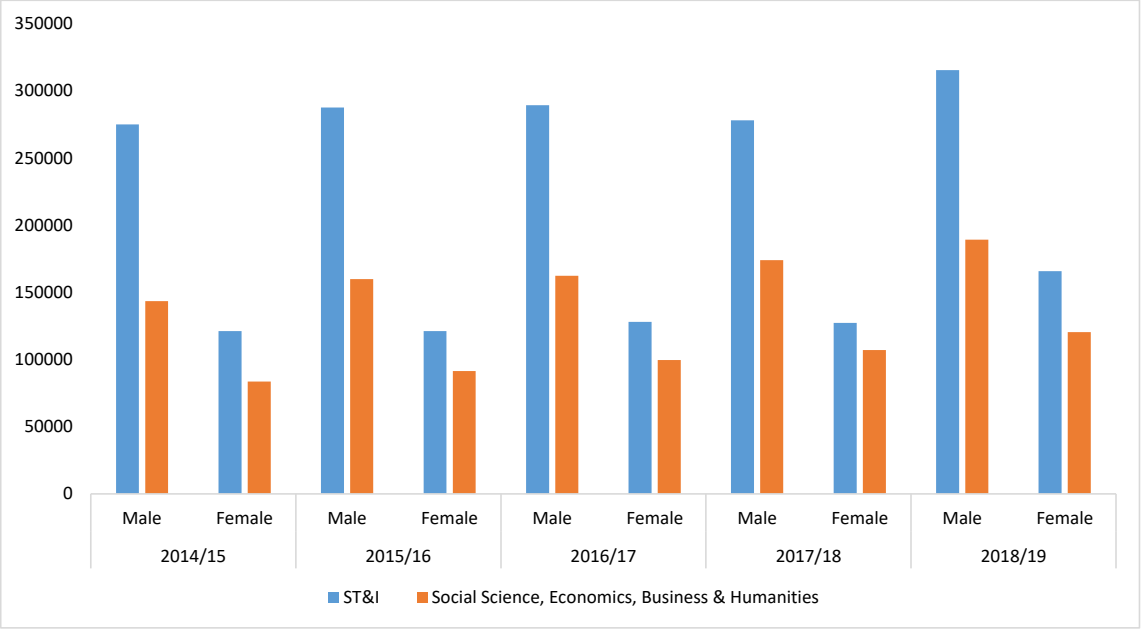

Figure 8. Student enrolment by Gender

For Haramaya University as a case study, the gender disaggregated academic staff position in the ST&I bands is disturbing, both in terms of adequacy and number of females. Out of the 712 staff with the rank of lecturer and above reported in 2019/20 academic year only 65 (9%) were female, with no females at the higher ranks of Professor and Associate Professor level and only 7 at the Assistant Professor level found in 2 out of the seven Colleges at the University (see Table 2). In addition to the gender disproportion, apart from the College of Agriculture and Environmental Sciences all the other six colleges do not have staff at the Professorial level. The College of Health and Medical Sciences with the highest number of females 32 (12.5%) has no professor and only 8 (3%) Associate professors. The College of Veterinary Medicine has no female staff with the rank of lecturer and above at all. This does not only represent low capacity and role modelling for female staff and student but a need to review staffing structure and capacity for ST&I research and development at the university in general.

The trend is different in Sudan, the third focus country of the FAWoVC initiative. Female students form the majority (55%) of enrolment at undergraduate level in higher education institutions and in some cases even reaching 70-80%. However, the majority of these female graduates are unemployed, and representation in research and development is low. Overall, even with Sudan, universities produced more graduates in social sciences and humanities than graduates from engineering and science between 1990 and 2019. In the year 2016/2017 for example, about 67,357 students graduated in social sciences compared to 15,958 from science and 13,434 from engineering field at the undergraduate level. Figure 9 gives a snapshot of gender-based enrolment by discipline in Sudan in 2017/18. Females had more participation in health studies and Educational Studies at 69% compared to Engineering studies at 27%.

Table 2. Gender disaggregated academic staff ranks at Haramaya University, 2019/20

Band	College/Institute	Lecturer		Assistant Professor		Associate Professor		Professor		Total	
		M	F	M	F	M	F	M	F	No	%F
1	Haramaya Institute of Technology	93	7	8	0	3	0	0	0	111	6%
	College Computing and Informatics	47	7	4	0	1	0	0	0	59	12%
2	College of Natural and Computational Sciences	49	1	16	0	7	0	0	0	73	1%
	Sport Science Academy	9	1	3	0	0	0	0	0	13	8%
3	College of Health and Medical Sciences	144	27	71	5	8	0	0	0	255	12.5%
4	College of Agriculture and Environmental Sciences	61	15	40	2	13	0	9	0	140	12%
	College of Veterinary Medicine	8	0	41	0	7	0	0	0	56	0%
	Total	411	58	183	7	44	0	9	0	712	9%

Source: Haramaya University, 3rd Quarter (2019/20) Performance Report (2020); HRMDD (2020)

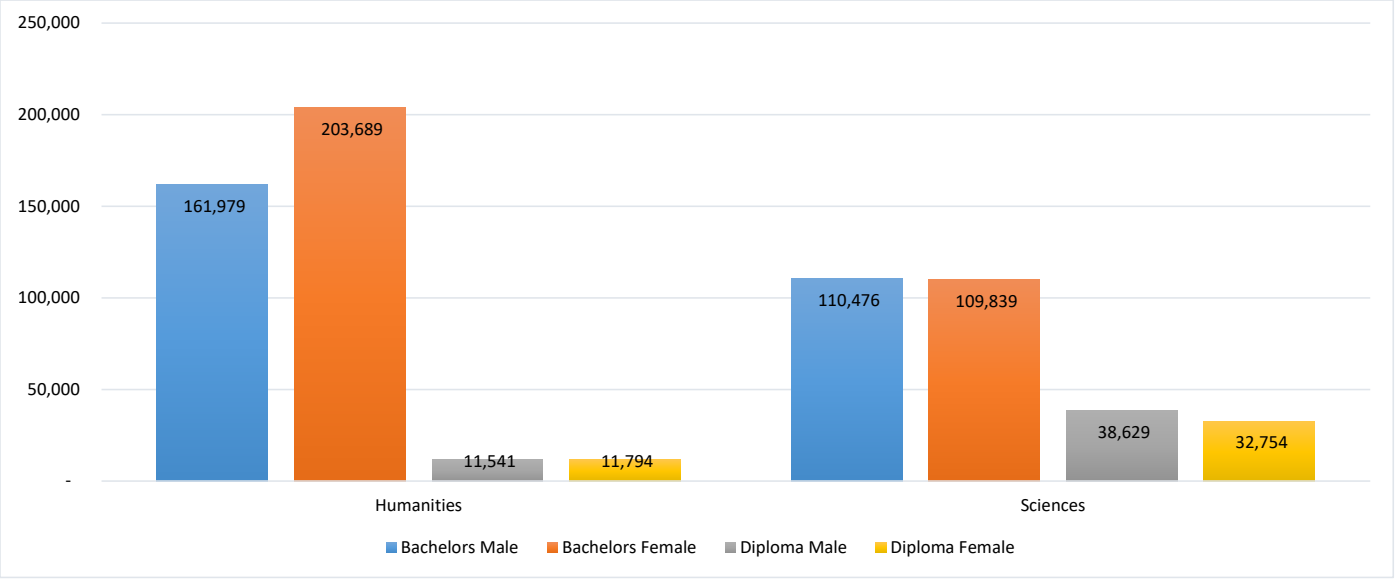

Figure 9. Summary of students enrolled in Higher Education Institutions by fields in academic year 2017-2018- Source: MOHE (2020)

The scenario in Sudan although unique, still has parallels with other countries on the continent. In Kodorfan University as a case study, males out number female enrolment at graduate MSc and PhD level. This disparity also applies at the academic staff level where females represented only 39% of the staff in the Sudan university and only 12% at professorial level. A further review of female professors reveals that there was only one professor in engineering, compared to 32 (16%) in agriculture and 28 (12%) in medicine (see Figure 10). Kordofan University with a total number of 740 staff 320 (43%) female has no female professor and only one female associate professor at Faculty of Agriculture.

The under-representation of women in ST&I and participation in higher education could be attributed to, among other reasons, policy, institutional and individual factors. These range from options for access through financial and other resource provisions, to career guidance and the time at which the choices to pursue the Arts & Humanities or ST&I is made. In all the four countries, the subject path/career choice is made at an early stage before students can adequately appreciate the desired professional orientation. This becomes a major hindrance for increasing the number of students pursuing STEM at the university level. For female students, it is compounded with peer pressure, stereo types and cultural inhibitions.

In the Mozambique education system, students have to choose between STEM and Social related subjects when they finish 10th grade (INDE, 2007). In Uganda students chose discipline orientation when they finish the lower secondary education before they are admitted for the higher school certificate. For Sudan, which currently does not have the intermediate secondary section, students from primary school move to higher school certificate and make the choices in the third and final year before they go to University. This could be the reason why there are more STEM students in university in Sudan than in the other two countries.

However, while the numbers are more favourable in Sudan, female students, are more inclined to care giving professions such as health and teaching while male students prefer to choose mathematics and engineering subjects because they have better job prospects after graduation and there is chance for self-employment. Sudan is not different from other African countries where female graduation in the sciences is inclined towards health and welfare as opposed to engineering or mathematics (Figure 11). Globally, only a fraction of female students select STEM-related fields in higher education at 3% for information and communication technology, 5% join mathematics and statistics courses, and 8% of students joining engineering, manufacturing and construction courses are female (United Nations, 2019).

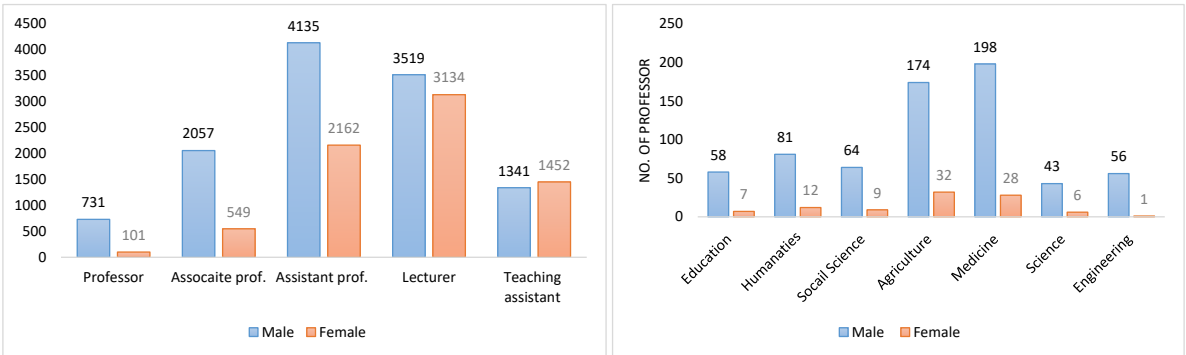

Figure 10. Gender disaggregation of Staff in Universities in Sudan

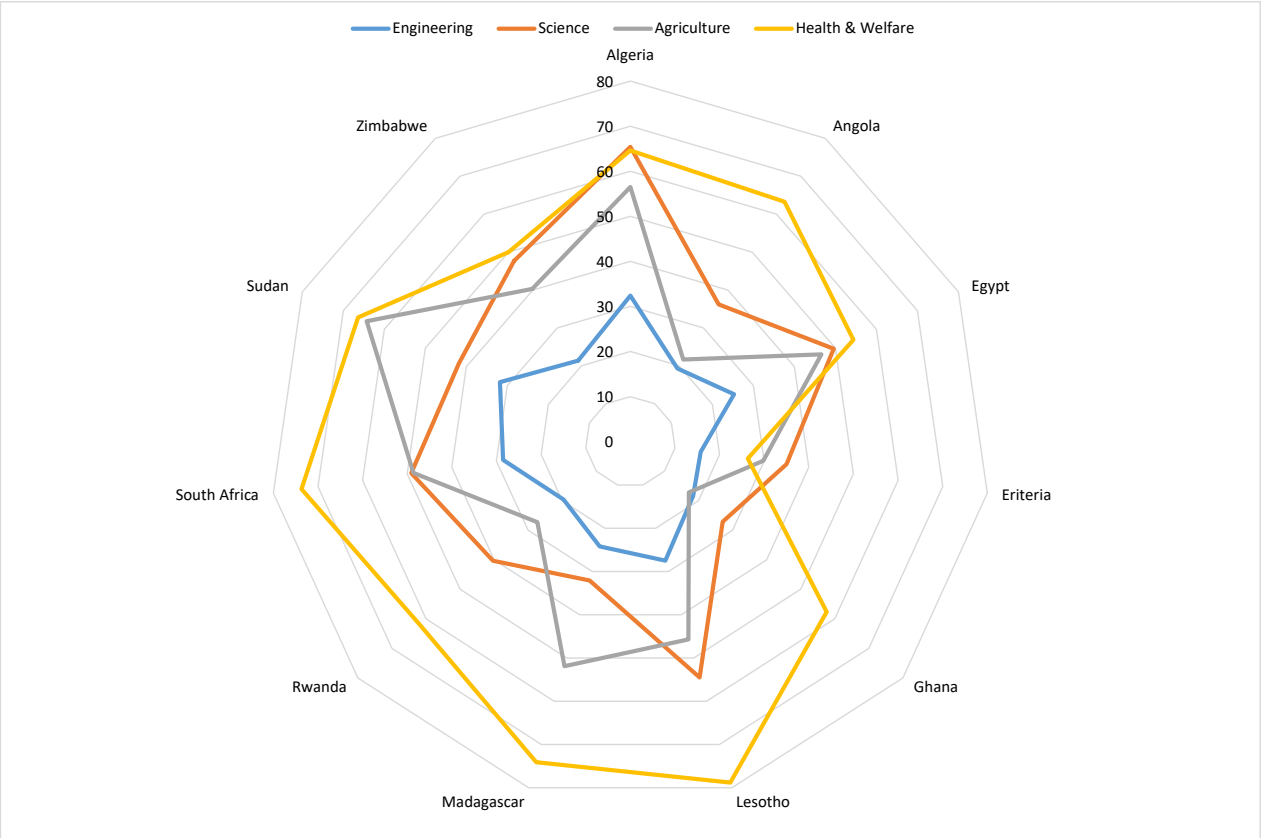

Figure 11. Women Graduates in Science Fields – UNESCO (2015)

Although gender participation in ST&I may be similar across the continent, there are variations. Disparities also exists across the education pipeline and by level. In all countries, the gender participation gap increases with progression across the education value chain. In Sudan, for example, cases of gender discrimination in academic programs at university level still exists. Some public universities limit engineering fields such as survey, petroleum and excavation engineering to boys only. In addition, several private institutions in Sudan similar to in Uganda do not offer science based academic programmes such as engineering. This is an indicator of capacity challenges to offer ST&I in African countries largely caused by under investment in R&D and or higher education. Poorly equipped laboratories and research fields do not have the capacity to attract applicants not to mention females in the ST&I programmes. This coupled with few role models, ST&I male dominated academic staff and inadequate mentorship limit female participation (ACBF, 2017).

Other reasons for limited participation in ST&I for both male and female students include the industrialisation level of the focus countries and the capacity to absorb graduates in gainful employment. Few countries have been able to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation as articulated by SDG 9. In Ethiopia for example, despite the affirmative action to increase Engineering and Technology graduates (Band 1), the Draft Education Development Road Map stated that under the current pace of the manufacturing sector development, it was less likely to employ all the graduates of engineering fields (Ministry of Education,

2018). Political leadership and affirmative action have also been instrumental in increasing female participation in Sudan and Uganda. For example, Sudan adopted the 40% government policy for female representation after the 2018 revolution. Consequently, the number of female Vice Chancellors increased to five, while the number of Deans increased to nine in AlNeelain University and 11 in Sudan University of Science and technology.

The challenges of female participation in higher education, ST&I notwithstanding, once admitted the percentage of female graduating is higher than for males. This positive graduation performance was also observed by Zavale *et al*. (2017) in Mozambique and evident from the graduation booklets at Makerere University in Uganda. It is however, different in Haramaya University where attrition rate for female undergraduate students although decreasing from 3.09 in 2015/16 to 1.85 in 2017/18 is still higher than for the males at 0.77%.

Gender –ST&I Strategy

Many countries in Africa have gender sensitive ST&I policies that aim at promoting the participation of women in science at all levels, but these are rarely implemented (ACBF, 2017). All countries considered by this study except Mozambique have gender strategies independent from the ST&I strategy. Countries recognize the importance of gender equity on livelihoods and poverty, but the linkage between gender and ST&I has not been explicitly articulated. On the other hand, where gender policies exists it has been noted that several focus on women as people and not the structural conditions that produce their disadvantage and by implication their limited participation in higher education or ST&I (Ssali, 2019). This comes out in Mozambique where the gender criteria is yet to prioritise women for research fund allocation but rather focuses on the gender dimension of team composition, the project beneficiaries and the project outcomes.

Further for Mozambique, the draft gender equity in higher education strategy [2018-2023] recognizes the need for greater interface between the two ministries (MCT and MINEDH) noting that the challenges of gender equity and women participation in STEM, start during primary and secondary education. Mozambique has ongoing work to constitute a women's forum for STEM to support dissemination and appreciation of STEM by women for women. The country is however, yet to formulate country specific policy instruments that promote female participation in ST&I.

In Sudan, the Ministry of Higher Education ST&I framework "Policies and Strategies of Science, Technology and Innovation" has no mention of gender or gender equity. Gender equity is mentioned in the framework of Ministry of Security and Social Development : National Policy of Women Empowerment 2007 (updated 2018) but there is no clear focus on ST&I issues.

In Uganda, gender and development is championed by three key government agencies instituted at intervals to drive the equity issues for practice and at policy level. The Ministry of Gender, Labour and Social Development was established in 1987, the National Women's Council in 1993, and the Equal Opportunities Commission was instituted in 2007. These are more inclined towards gender acculturation and independent of the ST&I development processes highlighted in section two of this paper. The National Gender Policy 2007 promotes gender mainstreaming in all government Ministry of Departments and Agencies (MDAs) and local governments, mandating women inclusion in leadership positions.

A significant number of laws targeting gender issues have been enacted in Uganda. Policies and programs that sought directly or indirectly to improve women's (social, educational, and health) conditions; economic autonomy, civic participation, and empowerment have been implemented. Gender equality is upheld in

local frameworks such as the 1995 Constitution, Vision 2040, National Development Plans (NDPs) and National Women's Council Act 1993. These do not pay specific attention to how gender influences ST&I or higher education. It is acknowledged that most of these policies are issue-specific, often deploying gender equality as a means to an end as opposed to mainstreaming it in implementation and without paying due attention to the drivers of gender inequality (Ssali, 2019). Yet Uganda is ranked favourably according to the different gender parity indices (WEF 2018).

Policy examples in Mozambique, Sudan and Uganda demonstrate that gender issues have gained recognition on the African continent. There is however, a need for a deliberate effort to ensure implementation that will promote not only female participation in higher education, ST&I but ensure active involvement in research and the 4th Industrial revolution skills (WEF, 2018). In Uganda, Ssali (2019) in her analysis and documentation of gender equality laws and policies in Uganda concludes that while strong gender-sensitive policies and legislative measures exist, implementation of these laws and policies remains a challenge.

Fitting within the Global Agenda for Gender and ST&I

International conventions provide frameworks, standards and guidelines of operations at national and local levels. Countries signing and assenting would imply that the frameworks would guide practice at the local level. The Sustainable Development Goals and Africa's Agenda 2063 for example, are clear about inclusivity and participation in ST&I and articulate the 1% of GDP target for R&D investment. Countries considered in this study subscribe to international protocols that would influence, gender, higher education, R&D as well as ST&I.

Mozambique

The Mozambican State is a signatory to various international and regional conventions that promote the principles and practices of gender equity and equality. Noteworthy is the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW); the Beijing Declaration and Platform of Action; the Sustainable Development Goals; and the SADC Protocol on Gender and Development. The importance of the Science and Technology sector was distinguished and highlighted within the Government development program in the year 2000, when first Ministry of Higher Education, Science and Technology was established.

Sudan

Sudan as one of the countries participating in the Global SAGA project funded by Swedish International Development Agency, aimed at development and deployment of a set of indicators concerning women's involvement in STEM in different countries has adopted initiatives such as the UNESCO Chair in Women, Science and Technology established in 2003 at the University of Sciences and Technology. The purpose of the Chair is to promote an integrated system of research, training, information and documentation activities in the field of Women, Science and technology. The Chair serves as a means of facilitating collaboration between high-level, internationally recognized researchers and teaching staff of the University and other institutions in the Arab States and Europe.

Sudan has advanced in moving towards public support to R&D in line with the SDGs and the African Union and UNESCO target of 1% of GDP. Through the Sudan Presidential Initiative for ST&I, the amount 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. Through this Fund, university staff members have been able to develop useful technological packages.

Uganda

Uganda subscribes to the Science, Technology

and Innovation Strategy for Africa (STISA), which the African Heads of State adopted in 2014 to accelerate Africa's transition to an innovation-led, knowledge-based economy by improving ST&I readiness in terms of infrastructure, professional and technical competence, and entrepreneurial capacity. Uganda similar to other countries in this study subscribes to Agenda 2063, which recognizes ST&I as the driver for global competitiveness as much as it underscores the need for gender equality and empowerment of women. At the East African Community (EAC) level, Uganda is a constituent member of the East African Science and Technology Commission (EASTECO) that champions The East African Regional Science, Technology and Innovation Policy that will ensure that universities are enhanced to be centres for excellence for investments in education.

On the gender front, Uganda in additional to national laws and policies is signatory to several convention that promote gender equality. These, among others, include The African Union Gender Policy, The Beijing Declaration and Platform for Action [1995] as well as the UN Security Council resolutions and the Commonwealth Secretariat's Gender Equality Policy [2012]. This subscription has neither translated into a full gender integration nor does it address issues of female participation in ST&I.

Ethiopia

Ethiopia has been among the countries striving to achieve the objectives of Agenda 2063 including ensuring gender equality in all spheres of life. The country has policies that are in line with sustainable development goal 5 (achieve gender equality and empower all women and girls). The second growth and transformation plan (GTP II) is considered as the development strategy to implement the SDGs (National Plan Commission of Ethiopia, 2017). Ethiopia has been among the African countries which incorporate ST&I in its long-term development plans and visions (African Academy of Sciences, 2018). Ethiopia is also a signatory of various global agreements such as the Convention on Elimination of all forms of Discrimination against Women (CEDAW), Convention of Civil and Political Rights, and Convention on Economic and Social and Cultural Rights. The Beijing Declaration and Platform for Action (BDPFA) and the Protocol to the African Charter on the Rights of Women in Africa (Maputo Protocol) were also conventions that Ethiopia ratified.

Initiatives to Promote Gender ST&I

All the four countries in the study have adopted legislation, policies and initiatives in one form or another to promote ST&I as well as gender equality at national level. Attempts have also been made at the higher education institution level to mainstream gender into university activities, promote female access to university education and most especially increase the number of female students admitted to ST&I academic programmes. Specific initiatives adopted at country level include establishing bodies to oversee the ST&I portfolio. This in some cases such as in Mozambique doubles as the Ministry in charge of Higher, Technical and Vocational Education.

Mozambique

In Mozambique, the Action Plan for Poverty Reduction (PARPA), Agenda 2025, and the five-year Government plan [2015-2019] that emphasizes the need to develop human and social capital through promotion of an inclusive education system with actions and polices that promote gender equity. In addition, the National Strategy for Science, Technology and Innovation [2010-2016], a Higher Education Strategic Plan [2012-2020] and a Gender Strategy for Education and Human Development [2016-2020] were developed to promote the Gender and the ST&I tracts.

The Gender Strategy [2012-2016] includes initiatives to encourage participation of females' students in S&T related subjects in order to influence an increase of university females' students in S&T programs. The strategy also includes initiatives to attract and retain women in key areas of science and technology. However, there are not yet any specific policy instruments that promotes female participation in ST&I areas. This gap is acknowledged in the Science and Technology Policy and Strategy and has been addressed in the new Gender Strategy for Higher Education [2018-2023]. At the SADC level, there is a move to constitute a Women's Forum for STEM. The Forum will promote and support dissemination of research and other works by women in STEM and is expected to increase promotion and appreciation of STEM by women for women, and build the role model culture (Zavale *et al*., 2017).

Uganda

In Uganda, several universities have instituted gender mainstreaming policies, and affirmative action for female to access university education commonly referred to as the '1.5 point scheme' which has been adopted by all public universities in the country. The policy provides an additional 1.5 points to female students to enable them access academic programmes and gives them an edge over their male counterparts. However, while this is the general policy direction, there have been cases where the cut off points for admission to the government scholarship favours male students. This is largely because admission is demand driven and the entry points are determined by the number of applicants for a specific programme, irrespective of their gender. It is also an indicator of the challenges that exist in ST&I participation and access to university education.

Beyond admission, Busitema University has been conducting gender sensitive tailor-made career guidance sessions in secondary schools in Eastern Uganda. This offers both sensitization about the potential and opportunities to pursue STEM academic programmes and provides role models for the lower secondary level.

Sudan

In Sudan, the Sudanese Researchers Initiative (SRI), established in 2009 has created a hub to promote idea generation, R&D and sharing among Sudanese researchers in a web-based platform. The mentorship platform further facilitates young and junior researchers to discuss their ideas openly. Other initiatives to support ST&I in Sudan, include:

a) The creation of Incubators to support technology- based and innovation-oriented entrepreneurs, provide a flexible environment and offer open workspace shared facilities, and management training to ensure the business will survive;
b) The UNESCO Chair for Woman in Science and Technology, under Sudan University for Science and Technology was launched in 2003. The Chair aims at promoting an integrated system of research, training, information and documentation activities in the field of Women, Science and Technology. The Chair serves as a means of facilitating collaboration between high-level, internationally recognized researchers and teaching staff of the University and other institutions in the Arab States and Europe. The UNSECO Chair launched the STEM Girls Club targeting gender participation in ST&I and is championing Global SAGA project funded by Swedish International Development Agency, aimed at development and deployment of a set of indicators concerning women's involvement in STEM in different countries in Sudan
c) Sudanese Women in Science Organization (SWSO) started in 2013 as an arm of Organization for Women in Science for Developing World (OWSD), with the objectives to strengthen capacity building programs, community development

programs, awareness campaigns, and establish central laboratories; and,

d) Innovation and Entrepreneurship Community (IEC), which started as an arm of Institute of Electrical and Electronic Engineers (IEEE) Sudan subsection, which was known as IEEE Sudan entrepreneurship Centre (ISEC). The IEC was launched in April 2013, with the objective to support the entrepreneurial activity in Sudan.

Ethiopia

Beyond the 70:30 policy to promote ST&I, Ethiopia has come up with initiatives to promote female participation. The Growth and Transformation Plan II (GTP II) [2015/16-2019/20] gives emphasis to gender equality at all educational levels and women's participation in the overall development of the country. In addition, the Higher Education Proclamation (Proclamation No. 650/2009) also strives to increase the proportion of women in senior positions, and as an affirmative action for students' enrolment into higher education institutions that gives special consideration to female students (Federal Negarit Gazeta, 2009). At the institutional level, policies to support women in leadership positions, excel in their performances and eliminate all forms of abuse have been developed.

The Ministry of Education Action Plan of the Education Sector Development Program (ESDP IV) incorporates females' equitable access to education at all levels as one of its objectives (MoE, 2015). The higher education road map drafted in 2018 proposes to further strengthen the affirmative action and to narrow the gender gap in higher education institutions.

The duration of all programs offered in higher education institutions has been changed to include an extra year to enable females have enough time to be familiar with the environment including the nature of the programs before choosing academic programmes. The initial year is dedicated to general courses with sufficient guidance and mentorship that will promote female participation in ST&I. In addition, female students receive tutorials to support their academic progress. Universities such as Haramaya and Hawasa have established STEM Centres to support high school students to excel in science education.

CONCLUSION AND RECOMMENDATIONS

The study gives the status of higher education, ST&I with a gender lens in Ethiopia, Mozambique, Sudan and Uganda. It provides a snapshot of the baseline of these attributes that can inform further interventions by the Forum for Women Vice Chancellors and the Regional Universities Forum for Capacity Building in Agricture (RUFORUM) efforts to increase the pool of women scientists in Africa. All countries in this study are aware of the challenges that exist in the ST&I gender terrain. Strategies have been developed and the regulatory and policy frameworks put in place to promote female participation in higher education and ST&I.

The Mozambique gender strategy for example, acknowledges the need to enhance articulation and collaboration between the various ministries to handle secondary schools' students and the challenges associated with the early selection of academic areas of focus. For all countries in the study, it emerges that keen attention has to be paid to the overall education ecosystem. Students and especially female students at the secondary school level need to be incentivized through role modelling and sensitization to offer STEM subjects. It is these students from the lower level that will translate into higher ST&I participation at the university level and beyond.

In Uganda, the adoption of the affirmative action has increased access and participation for females in higher education. However, because it is at the point of entry into the university it has not effectively increased the percentage share of girls taking ST&I programmes. Similarly, in

Ethiopia the 70:30 ST&I higher education policy is yet to reach the target and or translate into parity for males and females. The outcomes of these policies at national and institutional levels bring out the need to review and strengthen the criteria for ST&I scholarship and attribution at the lower levels of education.

A gender lens should be applied to research infrastructure, enhanced technical competencies of human resources through capacity building, training and curriculum reforms, in addition to offering incentives and motivation for females and their communities to join the STEM program. R&D financing should be broadly considered to include infrastructure, environment and incentives for effective female representation and participation within research and academic institutions.

In all countries and institutions alike, it is important to continually review policies and strategies, taking into consideration the changing gender terrain. This calls for constant research, dissemination and engagement of all actors on the gender attributes in higher education, research, ST&I. Policies dismantling the perceptions and stereo types about the performance and participation of females in the ST&I realm and workplace are urgent. Policy engagement and advocacy should target the socio-cultural, technological and financial aspects that will narrow the gender in education, ST&I as well as technical and leadership positions.

ACKNOWLEDGEMENT

This paper was commissioned by the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), as part of the Network effort to study the ST&I ecosystem and gender role across Africa. The country specific studies were funded by RUFORUM and FAWoVC through the Islamic Development Bank funding.

REFERENCES

ACBF. 2017. Africa Capacity Report 2017, Building Capacity in Science, Technology and Innovation for Africa's Transformation. Fairbairn Drive, Mt Pleasant, Harare, Zimbabwe, The African Capacity Building Foundation.

African Academy of Sciences. 2018. Africa Beyond 2030 Leveraging Knowledge and Innovation to Secure Sustainable Development Goals. Nairobi, Kenya.

Borland, J., Dawkins, P. Johnson, D. and Williams, R. 2000. Returns to Investment in Higher Education. The Melbourne Economics of Higher Education Research Program. Melbourne, The University of Melbourne.

Cornell University, INSEAD, WIPO. 2019. The Global Innovation Index 2019: Creating Healthy Lives—The Future of Medical Innovation. Ithaca, Fontainebleau, and Geneva.

Cornell University, INSEAD, WIPO. 2020. The Global Innovation Index 2020: Who Will Finance Innovation? . Ithaca, Fontainebleau, and Geneva.

Federal Negarit Gazeta. 2009. Higher Education Proclamation: . Proclamation No. 650/2009. . F. D. R. o. Ethiopia. Addis Ababa 15th Year No. 6.

INDE. 2007. Plano Curricular do Ensino Secundário Geral. Ministério de Educação e Cultura.

Ministry of Education, E. 2016. Education Statistics Annual Abstract, 2007 E.C. (2014/15). Ministry of Education, Addis Ababa, Ethiopia.

Ministry of Education. 2018. Ethiopian Education Development Roadmap (2018-2030). Ministry of Education, Addis Ababa, Ethiopia.

Ministry of Education, E. 2018. Education Statistics Annual Abstract, 2010 E.C. (2017/18). Addis Ababa: Ethiopia.

Ministry of Education, M. 2015. Education Sector Development Program V (ESDP

V) 2008 - 2012 E.C. 2015/16 - 2019/20 G.C: Program Action Plan. . Addia Ababa. Federal Democratic Republic of Ethiopia.

Ministry of Science and Higher Education, E. 2020. Higher Education Statistics Annual Abstract 2011 EC (2018/19). Addis Ababa: Ethiopia.

Montenegro, C. E. and Patrinos, H.A. 2013. Returns to schooling Around the World: Background Paper to the World Development Report 2013. Washington D.C, World Bank.

Muthumbi, J. 2015. Africa's women in science. WHO-TDR.

National Council for Higher Education (NCHE). 2013. The State of Higher Education 2011. Kampala, National Council for Higher Education.

National Council for Higher Education (NCHE). 2019. State of Higher Education and Training in Uganda 2017/18. Kampala, National Council for Higher Education.

National Plan Commission of Ethiopia. 2017. The 2017 voluntary national reviews on SDGs of Ethiopia: Government commitments, national ownership and performance trends. From: https:// sustainabledevelopment.un.org/content/ documents/16437Ethiopia.pdf

Nieuwenhuis, R., Munzi, T., MunziJorg, N., Omar, H. and Palmisano, F. 2018. Gender equality and poverty are intrinsically linked: A contribution to the continued monitoring of selected Sustainable Development Goals Project: In it together? Supporting women's employment to reduce economic inequality among all households UN Women.

Ssali, S. N. 2019. A matrix and analysis of Gender Equality laws and policies in Uganda. School of Women and Gender Studies, Makerere University, in partnership with University Forum on Governance under the Gender Equality Project.

Tesfa, B. 2015. Challenges of Ethiopian Researchers and Potential Mitigation with Ethiopian Science, Technology and Innovation Policy. 5th GKEN International Multidisciplinary Conference, Addis Ababa.

UNESCO. 2015. UNESCO Science Report, Towards 2030- Executive Summary. Paris, UNESCO.

UNESCO. 2019. Women in Science Fact Sheet No. 55. FS/2019/SCI/55.

United Nations. 2019. Gender and Science, Technology and Innovation Initiatives United Nations Interagency Task Team on STI for SDGs. United Nations, New York.

Watkins, A. and Ehst, M. 2008. Science,Technology, and Innovation Capacity Building for Sustainable Growth and Poverty Reduction. Washington DC, World Bank.

World Bank. 2016. Unlocking Firm Level Productivity and Promoting More Inclusive Growth: The Role of Innovation in Ethiopia. World Bank, Washington, DC. https://openknowledge.worldbank.org/ handle/10986/23792.

World Economic Forum (WEF). 2018. The Global Gender Gap Report 2018. World Economic Forum.

Zavale, N., Santos, L., Manuel, L., Dias, M.L, Khan, M., Tostão, E. and Mondlana, A. 2017. Decision-making in African Universities demand rigorous data: Evidence from graduation rates at Eduardo Mondlane University, Mozambique. *International Journal of Education and Development* 52: 122-134.