A scientometric analysis of the science system in Tanzania

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A thesis submitted to Stellenbosch University for the degree of Doctor of Philosophy (PhD) in Science and Technology Studies in the Faculty of Arts and Social Sciences

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March 2021

DECLARATION

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ABSTRACT

The main goal of the study was to conduct an assessment of the state of science in Tanzania. More specific objectives focused on the levels of research investment, human resources for S&T, and the research performance of the system. In addition we also investigated the challenges that young scientists in the country face.

Our study shows that Tanzanian expenditure in R&D remains still below 1% of GDP and lags behind several African countries including Kenya the sister EAC country. In spite of the slight increase in spending in R&D from 0.38% in 2010 to 0.53% of the GDP in 2013, there is still overdependence on international funding sources. It was also found that the lack of research funding and funding for research equipment are the biggest challenges in the performance of research for young scientists.

The study also found that Tanzania's human resources for S&T remains unacceptably small compared to several SADC countries, which results in relative low output per million of the population. However, it was revealed that there was a gradual increase in Tanzania scientific outputs from 339 publications in the year 2005 to 1389 publications in 2018 which is more than four times the growth of literature. In spite of the increase in the publications across all research fields, Tanzania dropped its position in world rank from position 74 in 2005 to position 80 in 2018..

Tanzanian science remains strong in its traditional fields: the relative strength analysis revealed that the agricultural and health sciences, and to a lesser extent, the social sciences, are the most active fields compared to the world output across these fields. The overall top five prolific R&D institutions in the production of scientific papers are the MUHAS, UDSM, SUA, NIMR, and IHI. International co-authorship is on the increase in most fields, but these trends probably reflect the growing participation of Tanzanian scientists in global health and agricultural projects rather than any substantive growth in research collaboration.

Our main recommendation is that the Tanzanian government commits to increasing its investment in R&D as aspired to by the R&D policy. In addition, the number of R&D personnel has to be increased to ensure that knowledge production continues to grow and the application of science, technology, and innovation for inclusive development is achieved.

OPSOMMING

Die hoof oogmerk van hierdie studie was om ‘n waardering te doen van die stand van wetenskap in Tanzanië. Meer spesifieke doelwitte van die studie het gefokus op die finansiering van navorsing, die menslike hulpronne vir wetenskap en tegnologie en die oorkopelende prestasie van die navorsingstelsel. Die studie het ook ontledings gedoen van die uitdagings wat jong wetenskaplikes moet oorkom in hul loopbane as wetenskaplikes.

Ons studie toon aan dat Tanzanië se besteding aan navorsing en ontwikkeling (N&O) onder die teiken van 1% van Bruto Binnelandse Produk (BBP) bly en dat dit selfs laer is as dié van sy buurland Kenia. Ten spyte van ‘n klein toename in die besteding aan N&O van 0,38% in 2010 tot 0,53% in 2018 as proporsie van BBP, is dit steeds die geval dat die wetenskapsisteem grootliks afhanklik bly van internasionale navorsingsfinansiering. Die studie het ook gevind dat die gebrek aan navorsingsfinansiering en spesifiek die finansiering van wetenskaplike toerusting van die grootste uitdagings is wat jong navorsers moet oorkom.

Die ontleding van die menslike hulpbronne vir navorsing toon dat Tanzanië nie goed vergelyk met die meeste van die Suid-Afrikaanse Ontwikkelingsgemeenskap lande nie. Alhoewel daar tussen 2005 en 2018 ‘n toename in publikasies was (van 339 tot 1389), het Tanzanië se posisie op die ranglys van wêreldlande verswak van posisie 74 in 2005 tot posisie 80 in 2018.

Die wetenskapsisteem in Tanzanië is steeds sterk in tradisionele velde soos landbounavorsing, mediese en gesondheidsnavorsing en, in ‘n mindere mate, die sosiale wetenskappe. Die vyf mees produktiewe navorsingsinstellings was MUHAS, UDSM, SUA, NIMR, en IHI. Internasionale mede-outeurskap in die meeste wetenskaplike velde het toegeneem. Maar dit is belangrik om te noem dat hierdie toename waarskynlik eerder gedryf word deur die groterwordende deelname van Tanzaniese wetenskaplikes in internasionele projekte as ‘n substantiewe groei in navorsingsamewerking.

Ons belangrikste aanbeveling is dat die Tanzaniese regering sigself moet verbind tot ‘n substansiële toename in besteding aan N&O soos eksplisiet in nasionale beleidsdokumente aangedui word. Verder is dit ewe belangrik dat die getal wetenskaplike navorsers in die land beduidend verhoog moet word ten einde te verseker dat kennisproduksie sal floreer en die toepassing van wetenskap, tegnologie en innovasie vir inklusiewe ontwikkeling sal realiseer.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank the following individuals:

- Prof. Johann Mouton, my supervisor , for his support and constructive feedback during my journey of this research work;
- Dr. Jaco Blanckenberg and Dr. Charl Swart , for their assistance and contribution to my research work particular in the bibliometric analysis and survey data from the Young Scientist Project in Africa;
- Mrs Marthie van Niekerk , Mrs Rolene Langford and Mrs Bernia Drake for the administrative, personnel and logistics support for the entire period of my study;
- My lovely wife Lucy Mbambe Maziku, for her moral and physical support during the entire period of my study;
- My family and friends, for being understanding and patient with me.
- Juanita Du Toit , for language editing of the thesis.
- To the Almighty Lord my God for his love, blessings, and care.

I would also like to acknowledge the contributions of the DST-NRF Centre of Excellence in Scientometrics and Science, Technology and Innovation Policy, which is hosted at the Centre for Research on Evaluation, Science and Technology (CREST) at Stellenbosch University, for allowing me, to use their resources and expertise.

FINANCIAL SUPPORT AND GRANTS

The Centre for Research on Evaluation, Science and Technology (CREST), the Robert Bosch Stiftung and the International Development Research Centre (IDRC), Canada, multinational funding agencies supported my research project. In December 2016, I was awarded the scholarship by Stellenbosch University to pursue my PhD studies at the Centre for Research on Evaluation, Science and Technology, the host of the DST-NRF Centre of Excellence in Scientometrics and Science, Technology and Innovation Policy Stellenbosch University, Cape Town, South Africa. The PhD program was part of the Young Scientists in Africa project which was undertaken by scientists at CREST and the Polytechnique Montreal Canada.

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LIST OF ABBREVIATIONS AND ACRONYMS

AOSTI	African Observatory of Science, Technology and Innovation
ARC	Average of Relative Citations
ARU	Ardhi University
ARUA	African Research Universities Alliance
AU	African Union
AU-NEPAD	African Union–New Partnership for Africa's Development
CAMARTEC	Centre for Agriculture Mechanization and Rural Technology
CASSOA	Civil Aviation Safety and Security Oversight Agency
CDTT	Centre for the Development and Transfer of Technology
COSTECH	Tanzania Commission of Science and Technology
CREST	Centre for Research on Evaluation Science and Technology
CUHAS	Catholic University of Health and Allied Sciences
CWTS	Centre for Science and Technology Studies of Leiden University
DAAD	German Academic Exchange Service
DANIDA	Danish International Development Agency
DESC	Departmental Ethics Screening Committee at CREST
DFID	Department for International Development of the United Kingdom
EAC	East Africa Community
EAHRC	East African Health Research Commission
EAKC	East African Kiswahili Commission
EAMFRO	East Africa Marine Fisheries Research Organization
EASTECO	East Africa Science and Technology Commission
ECOOM	Centre for Reseach and Development Monitoring in Leuven.
EDCTP	European and Developing Countries Clinical Trials Partnership
ERP	Economic Recovery Programme
ESRF	Economic and Social Research Foundation
FINNIDA	Finnish International Development Agency
FTE	Expressed as full-time equivalents
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
GLOSYS	Global State of Young Scientists
GTZ	German Technical Cooperation
HC	Headcount
HIV.	Human Immunodeficiency Virus

HKMU	Hubert Kairuki Memorial University
ICT	Information Communications Technology
IDRC	International Development Research Centre
IFS	International Foundation for Science
IHI	Ifakara Health Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IMF	International Monetary Fund
IMS	Institute of Marine Sciences
INASP	International Network for the Availability of Scientific PublicationS
IPI	Institute of Production Innovation
IPR	Intellectual Property Right
IRDP	Institute of Rural Development and Planning
ISCED	International Standard Classification on Education
IUCEA	Inter-University Council for East Africa
KCMC	Kilimanjaro Christian Medical Centre
KCMUC	Kilimanjaro Christian Medical University College
LPA	Lagos Plan of Action
LVBC	Lake Victoria Basin Commission
LVFO	Lake Victoria Fisheries Organization
MEST	Ministry of Education, Science and Technology
MNCS	Mean Normalized Citation Score
MSc.	Master of Sciences
MU	Mzumbe University
MUHAS	Muhimbili University of Health and Allied Sciences
NACOSTI	National Commission for Science, Technology and Innovation of Kenya
NCC	National Construction Council
NEPAD	New Partnership for Africa's Development
NFAST	National Fund for Advancement of Science and Technology
NGOs	Non-governmental Organizations
NIH	National Institute of Health
NIMR	National Institute for Medical Research
NLRI	National Livestock Research Institute
NM-AIST	Nelson Mandela African Institute of Science and Technology
NORAD	Norwegian Agency for Development Cooperation
NRF	National Research Foundation of South Africa

NSI	National System of Innovation
NUFFIC	Dutch Organisation for Internationalisation in Education
OAU	Organization of African Unity
OECD	Organisation for Economic Co-operation and Development
OUT	Open University of Tanzania
PhD	Doctor of Philosophy
R&D	Research and Development
REPOA	Research for Poverty Alleviation
RFS	Relative Field Strength
SADC	Sothern Africa Development Community
SAREC	Swedish Agency for Research Cooperation with Developing Countries a
SAUT	St. Augustine University of Tanzania
SciSTIP	DST-NRF Centre of Excellence in Scientometrics and STI Policy
SDC	Swiss Development Cooperation
SGCI	Science Granting Councils initiatives in sub-Saharan
SI	Specialization Index
Sida	Swedish International Development Agency
SIDO	Small Industries Development Organization
SMEs	Small and Medium Enterprises
SPSS	Statistical Package for the Social Sciences
S&T	Science and Technology
STI	Science Technology and Innovation
STIFL	Swiss Tropical Institute Field Laboratory
SUA	Sokoine University of Agriculture
TACRI	Tanzania Coffee Research Institute
TAFIRI	Tanzania Fisheries Research Institute
TAFORI	Tanzania Forest Research Institute
TALIRI	Tanzania Livestock Research Institute
TALIRO	Tanzania Livestock Research Organization
TANRIS	Tanzanian Research Information Services
TANU	Tanganyika National Union
TARI	Tanzania Agricultural Research Institute
TARO	Tanzania Agricultural Research Organization
TATC	Tanzania Automotive Technology Centre
TAWIRI	Tanzania Wildlife Research Institute
TCU	Tanzania Commission for University

TEMDO	Tanzania Engineering Manufacturing and Design Organization
TIRDO	Tanzania Industrial Research and Development Organization (TIRDO)
TNSRC	Tanzania National Scientific Research Council
TPRI	Tropical Pesticides Research Institute
TTMS	Telecommunications Track Monitoring System
TUMA	Tumaini University Makumira
TVLA	Tanzania Veterinary laboratory Agency
UDOM	University of Dodoma
UDSM	University of Dar es Salaam
UIS	UNESCO Institute for Statistics
UN	United Nations
UNCST	National Council for Science and Technology of Uganda
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
URT	United Republic of Tanzania
USAID	United States Agency for International Development
UTAFITI	Tanzania National Scientific Research Council
WB	World Bank
WHO	World Health Organization
WoS	Web of Science
YSA	Young Scientists in Africa

CHAPTER 1: INTRODUCTION

1.1 Introduction and rationale

Research evaluation has become an increasingly important 'tool' for many governments to demonstrate the value and relevance of scientific research as well as to set benchmarks for assessing national research performance against other science systems (Shao & Shen, 2012). Research evaluation aims to assess the research performance of a nation or institution and thus provides the basis for making decisions regarding resource allocation and priority-setting as well as meeting the demand for accountability. Such assessments can provide evidence-based information, which can be used to improve research (formative function) (Kuhlmann, 2003; McDonald & Teather, 1997; Reinhardt & Milzow, 2012). In research and development (R&D) institutions, assessment of research production and productivity provides evidence-based decisions on the recruitment, promotion, rewards, workload and resource allocations of researchers (Sife & Kipanyula, 2016:20). In recent years there has been an increase interest in the functioning of national research and innovation systems with a concomitant increase in interest in the evaluation of science systems (Rip, 2003:34). Accountability pressures are associated with the advent of new public management (NPM) and the related emphasis on the evaluation of research performance (Arnold, 2004; Rip, 2003, OECD, 2011; Lewis, 2014). Accountability usually includes the question "what did you do with the money?" Rip (2003:35). In this situation, "audit type methods" are applied in evaluation, where public research institutions are assessed on how they spend R&D funding (Geuna & Martin, 2003; Rip (2003:35).

Most of the R&D institutions in sub-Saharan Africa suffer from inadequate research infrastructure and equipment, low research capacity and capability, and inadequate research funding that invariably impacts negatively on the performance of research (Abrahams, Burke & Mouton, 2009; Jeenah & Pouris, 2010; Kotecha, Walwyn, & Pinto, 2011; Pouris, 2015; Toivanen & Ponomariov, 2011). It is thus essential to institutionalise research evaluation in science systems in order to assess the state of research performance in a country. This need for evaluating research performance also applies to Tanzania.

Tanzania was under a British colonial administration and got its independence in 1961. The United Republic of Tanzania is the union between Tanzania on the mainland (the then Tanganyika) and the Tanzanian Islands (Unguja and Pemba) which took place in 1964. The country is located in the Eastern part of Africa and is among the founder states of the EAC (Eastern African Community). The country is bordered by Uganda and Kenya to the north and Malawi, Mozambique and Zambia to the south and the Democratic Republic of Congo, Rwanda and Burundi to the western part.

The main economic sectors are agriculture, tourism, services, and industry. According to URT (2012:8), about 75% of the population live in rural settings and derive their economic livelihoods from agriculture (crop production, livestock keeping, and fisheries). The statistics show that in 2016 the country had a population of about 56 million people, with a growth rate of about 2.9%, which is relatively high for sub-Saharan Africa (URT, 2012:8; WB, 2016). According to the World Bank statistics, the Tanzanian GDP in 2017 was estimated to be US$936 (WB, 2017). Over the last decade, the average national economic growth has been 7% (Hanlin & Khaemba, 2017). Agriculture is the main employer for more than three-quarters of the population, in which 70% are subsistence farmers who depend on rainfall for cultivation (Lema & Majule, 2009).

The agricultural sector contributes about 28% of GDP, tourism 50 %, services 15% and the manufacturing sector 7% (URT, 2019). It was observed that the manufacturing, tourism, services and agriculture sectors grow at the rate of 10%, 7%, 4%, and 4% (Tanzaniainvest, 2020; WB, 2020:287) respectively. The slow growth of the agriculture sector, which employs the majority of the population in the country, could be attributed to low production and productivity, due to the low application of agricultural technologies and a poor marketing system in the country. The government needs to select priority sectors, like agriculture, in the agro-processing industry for value addition of agricultural produce and hence boost the national economy.

Science, technology and innovation (STI) have been acknowledged as vital tools for the implementation of the post-2015 development agenda and the sustainable development goals (SDGs) (ESCAP, 2015). It is important for developing economies, such as Tanzania, to embrace and apply STI to achieve sustainable social-economic development. Since its first STI policy, which was promulgated in 1985, the country has had several versions of STI policies, following reviews. The following are some of the issues which brought about the failure of the previous STI policies in the country.

Research and innovation investment is one of the major challenges facing the Tanzanian R&D system. A 2005 R&D survey report showed that the contribution of the Tanzanian government to expenditure on R&D investment over the period 1995 to 2004 was only 14%, while the contribution by foreign sources was 51%, own sources (31%) and domestic sources (4%) (COSTECH, 2005a). In 1995, the government established the National Fund for Advancement of Science and Technology (NFAST), a dedicated research fund to support research and innovation activities at least by 1% of Gross Domestic Expenditure to Research and Development (GERD) of the Tanzanian GDP. The NFAST is intended to support research projects, capacity building of researchers through postgraduate training (master's, PhD and post-doctoral), research infrastructure support, science and technology (S&T) awards, and other relevant S&T activities in Tanzania. The research survey findings of R&D funds flow show that the expenditure on research and development (R&D) was a mere 0.24% of GDP in 2004 (COSTECH, 2005b). The most recent United Nations Educational, Scientific and Cultural Organization (UNESCO) science report of 2015 shows that Tanzanian investment in R&D was equally low at 0.38% (UNESCO, 2015:560).

The research and innovation capacity of Tanzanian R&D institutions is relatively small compared to many African countries. The quantity and quality of research and innovation programmes are determined by several factors, including the capacity of human resources involved in the R&D activities. The 2005 report on R&D institutions shows that in 2004 Tanzania had 2078 researchers, of which two-thirds were from higher learning institutions, and one third from research institutions (COSTECH, 2005b). According to the African Union–New Partnership for Africa's Development (AU-NEPAD) (2019), in 2013 the human resources at Tanzanian R&D institutions numbered 6502 and the total R&D personnel full-time equivalents (FTEs) were 2915.9. Additionally, out of 6502 R&D personnel in the country there were 3400 researchers of which 26% were female researchers. The proportion of female researchers was only 26%. Tanzania and South Africa have more or less the same demographic population, but the research personnel headcount (HC) of South Africa in 2010/2011 was 55,531, which is almost ten times that of Tanzanian research human resources of 5,788 in 2010. According to the UNESCO report on the review of the Tanzanian higher education institutions (UNESCO, 2011), two of the challenges facing Tanzanian higher education institutions, are the small number of researchers, and under-qualified academic staff.

The majority of R&D institutions in Tanzania are also plagued by inadequate or dilapidated research infrastructure. In 2012, COSTECH, through the National Funds for Advancement of Science and Technology, supported the construction and renovation of 20 research facilities in livestock, agriculture, fisheries and medical research institutions (COSTECH, 2014). Development and strengthening of research infrastructure (laboratories and equipment) are vital to ensure the quality and quantity of research outputs, therefore the research-funding strategies and mechanisms should be devised and implemented to ensure S&T funding. The main goal of this study was to assess the state of science in Tanzania. More specifically the aim was to conduct a scientometric study of the research investment, research capacity and performance of the Tanzanian science system. To my knowledge, based on a comprehensive review of the literature, is no comprehensive scientometric study has yet been done the state and performance of the science system in Tanzania. It is hoped that the findings of this study will make a contribution to address this gap.

Scientometrics is the quantitative analysis of the performance and trends of research activities (Ramkumar, Narayanasamy, & Nageswara, 2016). Scientometrics can be employed in the assessment of the production and productivity of the science system in the region, country, institution, individual researcher level and so on. Scientometrics is essential for assessing research production, productivity, and impact, scientific field specialisations, collaborative networks, and patterns of scientific communications (Perron, Victor, Hodge, Salas-Wright, Vaughn & Taylor, 2017). It allows for the assessment of a wide range of science indicators, including comparisons and production trends of scientific fields at institutional or national levels (Pouris, 2012). Scientometric analysis is typically used as an instrument for evidence-based decision-making by the government, institutions or science funding granting bodies in planning, policy formulation and allocation of resources (Perron et al., 2017).

1.2 Science, Technology and Innovation system

This study aims to assess the performance of the science system in Tanzania over the period between 2005 and 2018. More specifically, the objectives are to asses level of research and innovation investment, the research and innovation capacity, research and innovation outputs and research and innovation impact of produced knowledge in the country. The study generally covered all R&D institutions in Tanzania. The study employed science history, scientometric tool, secondary survey and interview to evaluate the state of science in the country. The research project adopts the research and innovation performance framework proposed by Mouton (2015). The research and innovation performance framework has four dimensions which include research and innovation investment; research and innovation capacity; research and innovation outputs and; research and innovation impacts (Mouton, 2015). The dimensions have been disaggregated into research and innovation performance categories, together with the associated indicators as shown in Chapter 4.

Using descriptive and analytical information, this study presents an assessment of the science system in the country. As mentioned above the "science system" in this study consists of four main dimensions: research funding, research capacity, research outputs and research impact. According to (Mouton et.al. 2019) research and innovation investment and research and innovation capacity are key enablers of knowledge production (i.e. the funding and human resources capacity required to produce knowledge). Conceptualization in assessing the state of science system in Tanzania was adopted from the framework developed by Mouton (2015) for South Africa, which is specific for evaluation of research performance as presented in detail in Chapter 4 under analytical framework of science and innovation system. According to Sugimoto and Larivière (2018:1) the research performance is assessed by using inputs, outputs, and impact dimensions. According to the authors the common inputs indicators included the size and characteristics of the scientific human resources and research funding. The outputs include publication outputs and patents. The impact indicators measure the way scholarly literature has an academic impact and to the society in general.

1.3 Previous scientometric studies of Tanzanian science

Our review of the literature has revealed that very few scientometric or - more accurately bibliometrics – studies have been done of the state of Tanzanian science. Only a few bibliometric studies, mostly with a limited scope in terms of scientific fields, the number of institutions and coverage in time, have been conducted in the country. Yonazi and Middleton (1998) undertook a scientometric assessment of Tanzanian scientific production between 1987 and 1997, and identified 1796 scientific papers in total for the period. A bibliometric study of the state of science and technology in Africa between 2000 and 2004, reveals that Tanzania had produced 1368 (or 2.0%) of the scientific papers in Africa, lagging behind its neighbour, Kenya, which had 3231 (4.7%). South Africa produced 20,762 papers and Egypt 13,942, which together constitute 50% of the scientific publications on the continent (Pouris & Pouris, 2009:8). The findings of the African Union study on the assessment of the scientific production of African countries from 2005–2010 (AOSTI, 2014:13) show that the per capita number of scientific papers in Tanzania during this period was 15.6 compared to 30.6 in Kenya. The level of technology transfer and commercialisation of research and innovation outputs in Tanzania is still very low and the number of patents is insignificant.

Lwoga and Sife (2013) conducted a bibliometric study of research productivity and the impact of publications of just one field of science (traditional medicine) at only a single institution (Muhimbili University of Health and Allied Sciences). The bibliometric study by Sife and Lwoga (2014) assessed the research performance of academic librarians in Tanzania in terms of their publication productivity from 1984 to 2013. In addition to that, Sife and Kipanyula (2016) and Sife, Bernard and Ernest (2014) confined their analyses to mapping veterinary research and the productivity of forest researchers at Sokoine University of Agriculture. The existing bibliometric scholarship in Tanzania is confined to either specific institutions or specific fields.

According to the study by Mouton (2018) for the period 2005 to 2015 annual publication output by country in Africa indicated that South Africa is leading, followed by Egypt and other Maghreb countries (Tunisia, Algeria and Morocco), together with smaller but significant number of publication from Nigeria, Kenya, Tanzania and Uganda. The data also showed how skewed the distribution of publication production on the African continent is. Furthermore, the study indicated that the Tanzanian share of Africa's publication production was 2%. The findings from the study by Sangeda,& Lwoga (2017) covering the period 1991 to 2015 did indicated an increase of publication outputs in Tanzania

Bibliometric studies of publication production is only one measure of the relative decrease of research outputs at many Universities in African. Several studies covering the period between 1990 and 2005 indicated that research performance at former well-resourced and supported institutions including the University of Dar es Salaam in Tanzania had weakened; that research equipment and laboratories had suffered from a lack of maintenance (Mouton, 2018).

The bibliometric study by Confraria and Godinho (2015) covering the period 2007 to 2011 indicated that the East African countries (Tanzania, Uganda and Kenya) all have a high rate of international research collaboration. Other previous studies have indicated that, intra-African research collaboration rates are low when compared with oversees research collaborations. Interestingly, all of the three countries exhibit a high intensity of research collaboration and specialization in similar disciplines (Immunology, Microbiology). The study further showed that the scientific impact of publications from East African countries is above the world average in a few disciplines - Immunology, Clinical Medicine, Microbiology and Social Sciences. These countries seem to be creating knowledge and solutions that have scientific impact in areas that are directly relevant to their local public health problems, such as the development of treatments for infectious diseases and other health-related challenges.

The study by Lwoga, Sangeda and Sife (2017) also indicated the lack of of scientometric studies in Tanzania. According to the study the few available scientometric – more correctly 'bibliometric' studies - are in the areas of traditional medicine, librarianship, forestry, veterinary science and grantees of the International Foundation for Science. The other bibliometric studies in Africa which included Tanzania in the analysis include (Abrahams et al. 2009; Boshoff, 2009; Confraria & Godinho ,2015; Onyancha 2016;Pouris ,2010; Pouris & Ho, 2014; Sitienei & Ocholla, 2010; Tijssen, 2015). Sitienei and Ocholla's study conducted a comparison of the research and publication patterns and output of academic librarians in eastern and southern Africa from 1990-2006. In conclusion: there is as yet no recent comprehensive scientometric assessment which has been conducted to date for Tanzania. This study thus aims to contribute to the academic knowledge on the state of research performance in Tanzania and could possibly be used to inform policy change to improve R&D performance in Tanzania.

1.4 Research aim and objectives of this study

The broad aim of the study was to understand and assess the state of science in Tanzania through assessing the research performance of R&D institutions from 2005–2018. Through the application of basic scientometric and bibliometrics methodologies, the study assessed the volume of scientific publications, scientific publication trends, research funding and the impact of scientific knowledge in the R&D institutions in Tanzania. In addition to the application of scientometric methods, the study also analysed secondary data from a web-based survey conducted by the Young Scientists in Africa

(YSA) project team which was hosted at CREST. Among other things, the YSA project investigated the factors which negatively influence the performance of young researchers in 22 African countries including Tanzania. Additionally, the study analysed transcripts produced by the YSA project team during the interviews of selected researchers from Tanzania. Both survey and qualitative data applied in this study are the secondary data. The final assessment and findings of the state of science system have been summarized and presented in the form of a SWOT analysis framework.

The following were the specific objectives of the study:

1. To investigate investment in research and innovation investment in the Tanzanian science system.
2. To assess the research capacity of the science system in Tanzania and benchmark it to other similar science systems in Africa.
3. To identify the main trends in Tanzanian research and innovation outputs.
4. To identify the scientific impact of knowledge across the scientific fields in Tanzania from 2005–2018.
5. To identify the main factors that influence the research performance of scientists in Tanzania.

Based on the aim and the specific objectives of this research, the study sought to answer the following research questions:

1. What is the nature and extent of the investment in science in Tanzania?
    i. Who are the top research funders in Tanzania?
    ii. What are the main trends in government funding from 1995–2018?
    iii. What are the main trends in terms of investment by scientific field and institution?

2. What is the research capacity of the science system in Tanzania and how does it compare to other similar science systems in Africa?
    i. What are the features and size of the human resources base of Tanzanian R&D institutions over the period of 1995–2018?
    ii. What are the research collaboration rates in Tanzania (national, regional and international)?
    iii. How do research collaboration patterns differ between different scientific fields?
    iv. Is there an association between receiving research funding and collaboration?
    v. Are there gender differences in research collaboration?
3. What are the main trends in Tanzanian research and innovation outputs?
    i. What are the main trends of scientific publications between 2005 and 2018?
    ii. Which are the top R&D institutions in terms of publication outputs (volume)?
    iii. What is the Tanzanian relative field strength of scientific domain outputs in Africa?

iv. What is the sector-wide distribution of publication outputs?

4. What is the citation impact of Tanzanian publications between 2005 and 2018?
   i. What are the trends in the citation impact of Tanzanian science between 2005 and 2018?
   ii. Which are the high impact fields?
   iii. What is the Tanzanian positional analysis for produced scientific domains in Africa?

5. What are the main factors that enable or constrain the research performance of scientists in Tanzania?
6. How are these factors related to access to resources, networks and collaborations, mentoring and intentional support for the scientists in Tanzania?

1.5 Outline of the thesis

The thesis consists of nine chapters. Following the Introductory Chapter is a Chapter that provides an overview of the history of Tanzanian science pre- and post-independence. The aim of this chapter (Chapter 2) is to provide some context to the current state of governance and the institutional landscape of Tanzanian science. Chapter 3 is devoted to an overview of the science, technology and innovation landscape, and the legal and institutional frameworks, which govern the Tanzanian science system. In Chapter 4 I discuss the research design and methodology that was followed as far as the empirical part of the study is concerned. The remainder of the thesis (Chapters 5 to 8) is devoted to a discussion of the results of the scientometric analyses as well as secondary analysis of survey data. Chapter 5 presents the results of our analysis of investment in R&D in Tanzania. Chapter 6 is devoted to the analysis and findings of the human resources for S&T in Tanzania Chapter 7 contains the analysis and findings of a bibliometric analysis of publication outputs and citation impacts. Chapter 8 presents the results of our analysis of research performance in terms of collaboration. The thesis closes (Chapter 9) with a discussion of the main findings, recommendations, limitations of the study and the proposed future research.

CHAPTER 2: THE EARLY HISTORY OF SCIENCE IN TANZANIA

2.1 Introduction

2.1 The genesis of research in Tanzania

This Chapter gives an overview of the history of research in Tanzania pre and post-independence. In the conceptualization of the study, it was important to have deep insight on the history of science and research in Tanzania to provide a necessary context for the scientometric, secondary survey and qualitative data analysis of the study. Therefore, the first part of the historical study collected and analyzed the relevant information regarding the establishment and organization of the R&D institutions in Tanzania and the East Africa in general during the Germans and British colonial administration as well as post-independence of Tanzania.

Scientific research in Tanzania has a long history since the beginning of the German administration in 1900, when the first central veterinary laboratory at Mpwapwa, Dodoma was established. Zonal veterinary centres were then established in different zones of Tanzania, then called Tanganyika, until the British took over power over the East African member states in 1919. Under the colonial administrations, there was a distribution of research undertakings among the East African territories. Tanganyika specialised in malaria research, Kenya in forestry and veterinary sciences, Uganda in trypanosomiasis, virology and freshwater fisheries, and marine research in Zanzibar (COSTECH, 2005a). In 1948, the British colonial administration, under the East African High Commission, established joint research institutions in East Africa for the mutual benefit of all territories (COSTECH, 2007). After the independence of the East African partner states, the joint research organisations were included under the administration of the East African Community (EAC) from 1967 to 1977. These countries, during the early 1960s, maintained established research systems for food, health and livestock development. In the case of Tanzania, most of the agricultural research and development institutions were established during the colonial era and spread its network to all zones of the country after independence.

2.1.1 Livestock research institutions

As indicated above the first research facility in Tanzania was the central veterinary laboratory at Mpwapwa, Dodoma, which was established in 1900 by the German colonial government (COSTECH, 2007). In 1905 the Germans built the first cattle dip tank in East Africa at Mpwapwa, to control tick-borne diseases and *trypanosomiasis*. Figures 2.1 and 2.2 respectively show the veterinary research centre building and the Nunge dip tank at Mpwapwa, built by the Germans.

Figure 2.1: The veterinary research centre at Mpwapwa, the first research institution in Tanzania built by the Germans in 1900 (TALIRI, 2017).

Figure 2.2: Cattle dip tank at Mpwapwa, the first dip tank in the East Africa built by the Germans in 1905 (TALIRI, 2017).

According to Strachan (2004), malaria and sleeping sickness were the most serious threats during World War I. Therefore, in 1915 the Mpwapwa and Amani research centres were the key facilities for providing quinine for the treatment and control of malaria among the German soldiers. The quinine was produced in laboratories from the bark of Cinchoma tree (the Peruvian bark) which contains alkaloids including quinine. After World War I, the British government took over the three East African territories, including Tanzania, in 1919. From 1924 to 1929, the main research activities of the Mpwapwa veterinary centre focused on *trypanosomiasis* and rinderpest, simply because the diseases were pandemic and caused high mortality in cattle, sheep and goats in many parts of the country. (TALIRI, 2017).

From 1930 to 1938, the research centre expanded its research programmes and experiments, which included animal breeding to improve indigenous cattle breeds, animal nutrition, and pasture management. The Mpwapwa livestock-training centre was also established in 1939 as part of the veterinary research station (founded in 1900), and it served as a training centre for extension officers in basic veterinary courses. In 1954, the headquarters of the veterinary science and animal husbandry department moved to Dar es Salaam, leaving a chief veterinary officer at Mpwapwa in charge of the research laboratory, animal breeding station, livestock, and pasture research (TALIRI, 2017). After the country gained independence, the research institution changed names: to the Tanzania Livestock Research Organization (TALIRO) from 1981 to 1989, the National Livestock Research Institute (NLRI) from 1989 to 2012, and the Tanzania Livestock Research Institute (TALIRI) as from 2012 to date (TALIRI, 2017).

2.1.2 Agricultural and forestry research institutions

The history of forestry research in Tanzania started in 1902 at the Amani silviculture research station in the eastern Usambara highlands in the Muheza district of the Tanga region. According to Nowell (1933), the research station was established under the leadership of Dr. Franz Stuhlmann, who was the director of the department of surveying and agriculture of the German administration in East Africa. The Amani research station was one of a number of famous world-class research stations during World War I, which produced quinine used by the German troops (Strachan, 2004). The German scientists introduced several varieties of foreign tropical plants of economic value including herbs, shrubs, and trees, both exotic and indigenous. According to the East African report (EAC, 1925:86), they included small plants, trees such as coffee, tea, and cocoa, plants of medicinal value, rubber, fibres, spices, plants producing oil, tannin, dyes, gums and resins, as well as a variety of fruits, timber trees, ornamental shrubs, economic and ornamental palms.

In 1926, the British colonial government re-established the research station as the East African Agricultural Research Station serving all the East African states. The research institute attracted many prominent scientists, including P.J. Greenway, G. Milne and R.E. Moreau (Hamilton & Mwasha, 1989:42). In 1951, the institute was renamed as the East Africa Malaria Institute and served all the British East African territories by conducting malaria research. In 1954, the institute was renamed again as the East African Institute of Malaria and Vector-borne Diseases. After the demise of the East African Community in 1977, the research institute was renamed the Amani Medical Research Centre and became part of the National Institution for Medical Research which was established in 1979 (NIMR, 2017a).

The Ukiriguru cotton research station, which is located in the Misungwi district, in the Mwanza region, was established in 1930 by the British scientists (Hjerppe, 1979). The main objective of the research institution was to undertake cotton research, particularly on breeding, pathology and the management and control of insects. The British East Africa report to the British parliament among other things also emphasised the economic value of cotton farming in Tanzania during the colonial era.

> We are satisfied that if any progress is to be made in cotton growing in Tanganyika, and there are few parts of the world where there are greater opportunities for its successful cultivation, the utmost watchfulness and efficiency on the part of the agricultural department is essential (EAC, 1925:119).

During the colonial era, agricultural research in Tanzania focused on the major cash crops for export, particularly cotton, coffee, sisal, tobacco, and tea. Cotton was cultivated in the lake zone, western zone, eastern and the northern zone of Tanzania and contributed to the income of about 40% of Tanzania's population (USDA, 2001). Good agronomic practices and using the right varieties of seeds are crucial to ensure high levels of production and productivity of cotton. The Ukiriguru cotton station also established the agricultural training centre in 1935, which served as a training centre for agricultural extension officers to improve cotton farming practices.

Figure 2.3: The Ukiliguru cotton research station.

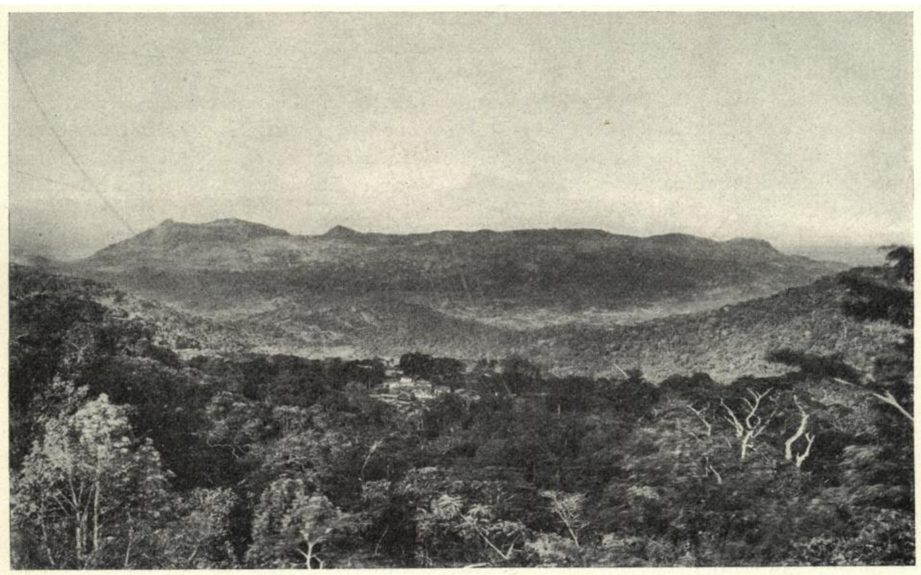

Figure 2.4: Amani forest

2.1.3 Medical research institutions

German scientists introduced medical research in Tanzania in the early 1900s, before World War I. Drs Robert Koch and Gustav Giemsa were among the prominent scientists who pioneered medical research and the diagnosis of important diseases, particularly malaria and tuberculosis, during the German administration (NIMR, 2017b). According to the National Institute for Medical Research (NIMR, 2017b), the sleeping sickness service unit in Tabora is the oldest medical research institution in Tanzania, and was established in 1922 by the British colonial government.

During colonial times, a vast area of the western and lake zones of Tanzania were heavily infested with tsetse flies (*Glossina morsitans*), the potential vectors for the transmission of sleeping sickness in humans and *trypanosomiasis* in animals. As EAC (1925) notes, tsetse flies were among the serious issues before and after World War I in most parts of Tanganyika, Uganda, Nyasaland, and Northern Rhodesia. Therefore, the main purpose of the sleeping sickness service unit in Tabora was to provide treatment and surveillance of *trypanosomiasis* for both humans and animals. In Tanganyika, Mr C.P.M. Swynnerton, the director of the game preservation department, and the principal medical officer, Dr J. O. Shircore, jointly conducted research on tsetse flies with Sir David Bruce to ensure the vectors and disease came under control.

The Ifakara Health Institute (The Swiss Tropical Institute Field Laboratory) is one of the prominent research institutions in Tanzania and was established before independence by Professor Rudolf Geigy. Tanner et al. (1994) note that the Archdiocese of Mahenge, the founder of the St. Francis hospital, invited Prof Geigy and other staff of the Swiss Tropical Institute (STI) in Ifakara in 1949. The Swiss Tropical Institute Field Laboratory (STIFL) was one of the well-known medical research stations, which was established in Ifakara, Morogoro in 1957 through the great efforts of Prof Geigy, the founder of the Swiss Tropical Institute (Tanner et al., 1994:154–155). In the beginning, the STIFL was mainly conducting research on malaria and tick-borne relapsing fever, which were the common tropical diseases around the area. The STIFL was transformed into the Ifakara Centre in 1991, an affiliate institution of the National Institute for Medical Research (NIMR). The Ifakara Centre was then reorganised and transformed into the Ifakara Health Institute (IHI) in 2008, still under the affiliation of NIMR (IHI, 2017). The Ifakara health institute, as the research, training, and operational research institute, is well known as the organisation which plays a great role in the control of and fight against malaria, a very important economic disease in the country. The institute, in collaboration with internal and external partners, also implement malaria vaccine trials.

2.1.4 Fisheries research institutions

At the beginning of the British colonial administration, research and science focus was mainly on agriculture, forestry, medicine, and anthology. Fisheries research across British East Africa was given priority towards the end of World War I, since the British administration worried about the shortage of protein for the British citizens (Jennings, 2011). The situation strongly influenced the British government towards the application of science and technology to improve the production of marine resources in the East African territories. According to Jennings (2011), the great efforts of John Oliver Borley and Charles Frederick Hickling, who were the British fisheries advisors at different times, came up with comprehensive strategies for marine research, particularly in the tropical ocean.

The East Africa Marine Fisheries Research Organization (EAMFRO) was established in 1951 in Zanzibar with the mandate of carrying out marine research in Zanzibar and along the coast of East Africa. According to the annual report (EAMFRO, 1962), the narrow strip of the continental shelf along the coastline of East Africa, was the basis for indigenous canoe fishing with low fish catches. The annual report came out with important recommendations for Zanzibar, Tanganyika and Kenya, territories to improve commercial fishing production through tapping vast fisheries resources by using large fishing equipment, which can go to the deep sea. The report was used to increase the catching of marine resources along the eastern Africa coast in order to mitigate the shortage of protein in Europe. Certainly, marine research during colonial times triggered an opening of fisheries research centres in the Great Lakes of Tanganyika territories even after independence. The Tanzania Fisheries Research Institute (TAFIRI) currently is mandated to conduct marine and freshwater fisheries research in Tanzania.

The table below summarises the main dates in the early history of the establishment of research institutions in Tanzania.

Table 2.1: Chronology of R&D institutions in Tanzania (Tanganyika) 1900–1948

Year	Location	R&D Institution
1884/1885	**Germany acquired German East Africa (Tanganyika, Kenya and Uganda)**	
*1900	Mpwapwa	Central Veterinary Laboratory
*1902	Amani	Silviculture Research Station
*1905	Mpwapwa	Livestock Production Centre
1919	**The British East Africa administration after the World War I**	
1921	Dar es Salaam	Central Government Chemist Laboratory
1922	Tabora	Sleeping Sickness Unit
1925	Dodoma	Mineral Resources Library
1930	Ukiliguru	Cotton Research Station

Year	Location	R&D Institution
1930	Tumbi	Veterinary Research Station
1934	Lyamungu	Coffee Research Station
1934	Mlingano	Sisal Research Station
1943	Ilonga	Maize Research Station
1945	Arusha	Tropical Pesticide Research Centre
1946	Mbimba (Mbozi)	Coffee Research Station
1951	Amani	East African Malaria Institute
1951	Zanzibar	East African marine Fisheries Research Organization
1954	Dar es Salaam	Veterinary and Animal Husbandry Division
1954	Mwanza	East African Institute for Medical Research
1957	Ifakara	Swiss Tropical Institute Field Laboratory
1961	**Tanzania (Tanganyika) achieved independence**	

* Introduced by the Germans Data Source: (Hjerppe, 1979; COSTECH, 2007)

2.2 Research coordinating mechanisms in the East Africa 1948–1977

In 1924, the British colonial government, through a special task force, collected information on the economic ventures in the East African territories. One of the terms of reference for the task force was to report on the actions to be taken to accelerate the economic development of the British East African territory and policy coordination on issues such as cotton farming, transportation and the control of human, animal, and plant diseases (EAC, 1925:3). The task force did its job by collecting the required information from Tanzania, Kenya, Uganda, Northern Rhodesia and Nyasaland and reported to the British Secretary of State for the colonies, who presented the report to the British Parliament in 1925. One of the findings of the task force was the potential riches of the East Africa territories with vast wonderful arable land for agriculture, adequately watered and capable of yielding economic crops of almost all tropical, subtropical, and temperate varieties. The report also showed vast forests containing exportable timbers of economic value in the Usambara highlands (Amani) in Tanzania, Kenya and some parts of Uganda.

Apart from the huge economic potential discovered in the areas, it was also noted that humans and animals were at great risk of suffering from insect-borne diseases, and the disease prevalence was high. The tsetse flies and mosquitoes were outstanding vectors for the transmission of *trypanosomiasis*, and malaria to animals and humans respectively (EAC, 1925). The report shows that between 1901 and 1905 there was an outbreak of sleeping sickness in the islands of Lake Victoria, which claimed more than 300,000 people's lives. The other serious diseases were leprosy, tuberculosis, syphilis, and dysentery. Certainly, the findings of the task forces formed the basis for the strengthening and establishment of agricultural, livestock and medical research institutions in East Africa. Figure 2.5

below shows a map of Tanzania with the distribution of R&D institutions during the colonial administration.

The British Secretary of State for the colonies established the East African High Commission in 1948. The Commission was comprised of three governors, one each for Tanzania (then Tanganyika), Kenya and Uganda. The Commission was responsible for the administration of inter-territorial matters across the three territories, which included various research organisations, an income tax department, a civil aviation directorate, a statistics department, a customs and excise department, a meteorological department, the Royal East African Navy and the department of economic coordination (UN, 1959:23).

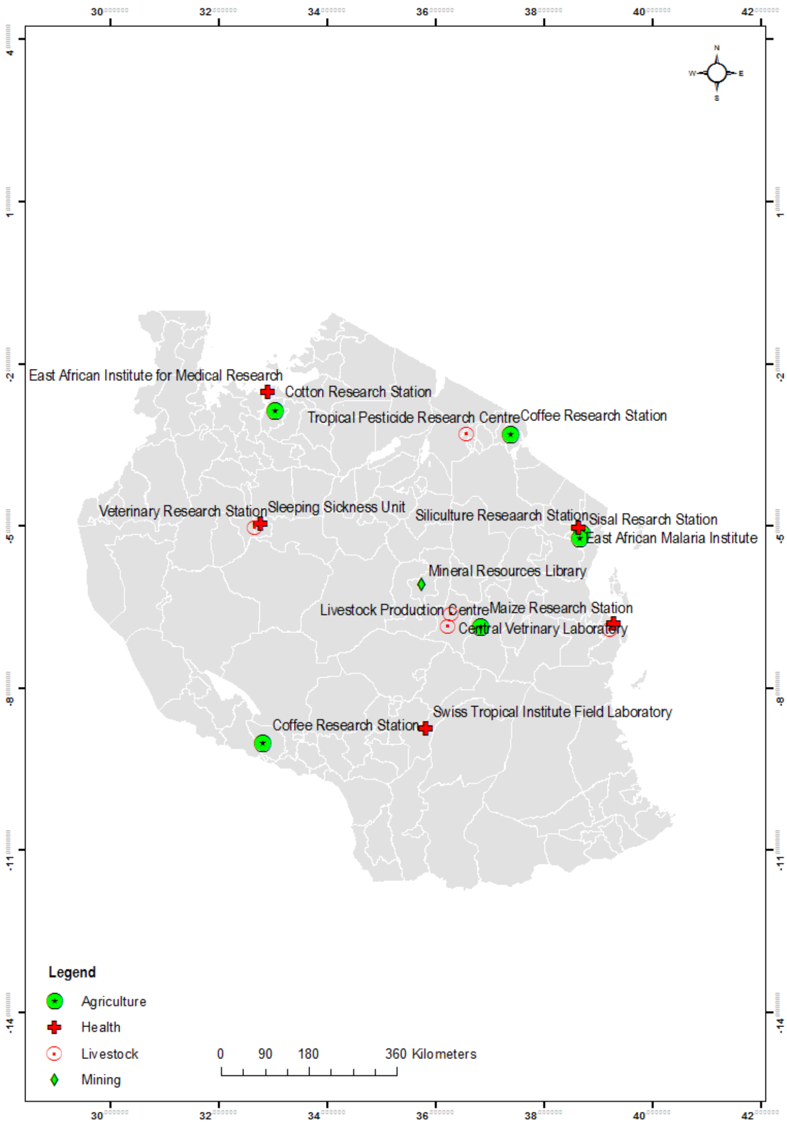

Figure 2.5: Map of Tanzania showing R&D institutions established during the colonial era 1900–1948.

According to the UN report on strengthening science and technology in Africa (UN, 1959), the East African Commission administered several joint research institutions for the benefit of all three territories. The research institutions are the East African Medical Survey and Research Institution, the East African Institute of Social Research, the East African Industrial Research Board, the East African Agriculture and Forestry Research Organization, the East African Trypanosomiasis Research Organization, the East African Marine Fisheries Research Organization, and the East African Inland Fisheries Research Organization. Other research institutions are the East African Council for Medical Research, the East African Virus Research Institute, the East African Institute of Malaria and Vector-Borne Diseases, the East African Veterinary Research Organization, the East African Agricultural and Fisheries Research Council and the Desert Locust Survey. The administrative and financial support for the research bodies came from all the three territories under the British colonial government.

The East African High Commission existed from 1948 to 1961, when Tanzania became independent from the British administration in 1961, followed by Uganda in 1962, and Kenya in 1963. From 1961 to 1967, after the independence of these states, the joint East African research organisations were under the East African Common Services Organization (COSTECH, 2007). From 1967 to 1977, these R&D institutions were under the administration of the East African Community, which was disbanded in 1977. Thereafter until now, the individual countries run these R&D institutions. Table 2.2 and Figure 2.6 present a list and a map of R&D institutions that were under the umbrella of the three East African territories from 1948–1977.

Table 2.2: The East African cooperation in R&D 1948–1977

Year	R&D institution	Sector	Location
			Tanzania
1945	East African Pesticides Research Institute	Agriculture	Arusha
1951	East African Malaria Institute	Medical	Amani
1951	East African Marine Fisheries Research Organization	Fisheries	Zanzibar
1954	East African Institute for Medical Research	Medical	Mwanza
1963	University of East Africa, University College of Dar es Salaam	Mixed	Dar es Salaam
1970	East African Sugarcane Breeding Centre	Agriculture	Kibaha
			Kenya
1947	East African Leprosy Research Centre	Medical	Alupe
1948	East African Agricultural and Forestry Research Organization	Agriculture	Muginga
1948	East African Industrial Research Board	Industrial	Nairobi

1949	East African Veterinary Research Organization	Livestock	Muguga
1960	East African Tuberculosis Research Centre	Medical	Nairobi
1963	University of East Africa, Nairobi University College	Mixed	Nairobi

Year	**R&D institution**	**Sector**	**Location**
			Uganda
1947	East African Freshwater Fisheries Research Organization	Fisheries	Jinja
1950	Makerere University College of East Africa	Mixed	Kampala
1950	East African Virus Research Institute	Medical	Entebbe
1956	East African Trypanosomiasis Research Organization	Medical	Tororo
1963	University of East Africa, Makerere University College	Mixed	Kampala

Data source: (Hjirppe, 1979; COSTECH, 1990; COSTECH, 2007; UDSM,2017;)

Figure 2.6: Map of Tanzania, Kenya and Uganda showing cooperation in R&D, 1948–1977

2.3 Sectoral R&D institutions after the collapse of the East African Community in 1977

Tanzania established several sectoral research institutions from 1979–1985 following the demise of the East African Community (EAC) in 1977. These sectoral research institutions were established by an act of parliament and are semi-autonomous under the different sectoral parent ministries as shown in Table 2.3. The established research institutions faced several challenges, including the shortage of scientists, inadequate research infrastructure and funding for research activities because of insufficient government financial support, due to the economic decline of the Tanzanian Gross Domestic Product (GDP).

Table 2.3: Affiliations of Tanzania sectoral R&D institutions established before the collapse of the EAC

Institution	Year
University of Dar es Salaam	1970
Building Research Unit (under Prime Minister's Office)	1971
Tanzania Food and Nutrition Centre	1973
Small Industries Development Organization	1973
Tanzania Bureau of Standards	1975
Uyole Agricultural Research Centre	1976
Tanzania Industrial Studies and Consulting Organization	1976

Source: COSTECH, 2007

In 1981, the government launched the National Economic Survival Programme (NESP), the economic recovery initiative following the decline of the Tanzanian Gross Domestic Product (GDP) brought about by the oil crises in 1973 and 1978, the breakdown of the East African Community in 1977 and the Kagera war in 1978/79. One year later, NESP was followed by three years of the Structural Adjustment Programme (SAP) from 1982/85 to solve the economic difficulties of the country (URT, 1996).

In the early 1980s, when the first Tanzanian Science and Technology Policy was in the making, the country was also undergoing macro-economic reforms to recover from the economic shocks that occurred in the 1970s (URT, 1996). In 1986, the government again launched the Economic Recovery Programme (ERP), based on IMF agreements to stimulate positive economic growth per capita and reduce the inflation rate. This was followed the Economic and Social Adjustment Programme (ESAP) with the World Bank in 1991 (Hyden & Karlstrom, 1993). These measures imposed by the World Bank and IMF brought about significant reform and amendment for many sectoral policies in Tanzania, including the National Higher Education Policy of 1999 and the Tanzania Science and Technology Policy in 1996 (URT, 1996).

A number of research institutions was established after the demise of the EAC from 1979 onwards (Table 2.4 below) The National Institute for Medical Research (NIMR), was established in 1979 and is the national body mandated to conduct medical and health research in Tanzania. The NIMR coordinates research activities from the Headquarters in Dar es Salaam, and discharges its duties through eight research centres, which were strategically distributed in the different zones of Tanzania with specific medical research undertakings (NIMR, 2017b). These research centres are in Amani, Tabora, Mbeya, Tukuyu, Ngongongare, Mwanza, Tanga and Muhimbili.

Table 2.4: Sectoral research institutions established after the collapse of the East African Community in 1977

Institution	Year
NIMR	1979
TPRI	1979
TIRDO	1979
Institute of Marine Sciences (IMS)	1979
National Construction Council (NCC)	1979
TAFORI	1980
TALIRO	1980
TARO	1980
TAFIRI	1980
TAWIRI	1980
TEMDO	1980
Institute of Rural Development and Planning (IRDP)	1980
CAMARTEC	1981
IPI	1981
Tanzania National Radiation Commission	1983
TATC	1985

Data source: (TNSRC, 1980; COSTECH, 2006).

According to TPRI (2017), the Tropical Pesticides Research Institute (TPRI) was established in 1979 and is mandated to conduct research on tropical pests affecting plants, animals and humans (TPRI, 2017) under the parent ministry of agriculture. Originally, it was established in 1945 and known as the East African Pesticides Research Institute under the British administration to serve all three East African territories (Tanzania, Kenya, and Uganda). From 1979 to 1985, the Tanzanian government also established industrial and engineering research institutions to cater for various needs for mechanisation and industrial development for social economic development of the country. The research institutions included the Tanzania Industrial Research and Development Organization (TIRDO), the Tanzania

Engineering Manufacturing and Design Organization (TEMDO), the Centre for Agriculture Mechanization and Rural Technology (CAMARTEC), the Institute of Production Innovation (IPI) and the Tanzania Automotive Technology Centre (TATC).

The Tanzania Forestry Research Institute (TAFORI) and the Tanzania Wildlife Research Institute (TAWIRI) are natural resources research institutions mandated to carry out forestry and wildlife research respectively, to ensure sustainable management and utilisation of natural resources. Both TAWIRI and TAFORI were established in 1980 and are under the Ministry of Natural Resources and Tourism (TAWIRI, 2017; TAFORI, 2017).

The Tanzania Agriculture Research Organization (TARO) and the Tanzania Livestock Research Organization (TALIRO) were established in 1980 under the ministry of agriculture with the responsibility of undertaking agriculture and livestock research respectively. However, both research institutes were dissolved and reformed in 1990 and came directly under the department of research and development in the ministry of agriculture. TARO was reorganised under different names as the agriculture research institute (1990), under the department of research and development. In 2016, the new agriculture research institute was formed and named as the Tanzania Agricultural Research Institute (TARI) (URT, 2016a). The National Livestock Research Institute (NLRI) was renamed after the dissolution of TALIRO, and existed up to 2012 when the newly established Tanzania Livestock Research Institute became operational under the Parliament Act no. 4 of 2012 (URT, 2012). Globalisation and trade liberalisation occurred in the 1980s and 1990s. That put pressure on the government expenditures to support the newly established and existing research and development institutions in the 1980s, still has a negative effect on the current situation of R&D support in Tanzania. As a survival strategy, these R&D institutions embarked on international funded research activities that did not necessary focus on the research priorities of the country (URT, 2010:7).

2.4 Research cooperation in the new East African Community

The new EAC is a regional intergovernmental organisation, comprised of six countries namely Burundi, Kenya, Rwanda, South Sudan, Tanzania, and Uganda. Its headquarters is in Arusha, Tanzania, as it was before it collapsed in 1977. The new EAC was re-established in 2000 with the three original countries of Kenya, Tanzania, and Uganda. In 2007 Rwanda and Burundi joined the Community, and lastly South Sudan in 2016 (EAC, 2018a).

Previously, during the British colonial administration and even after the independence of the three partner states of Tanzania, Uganda, and Kenya, there were a number of joint research institutions and collaborations among these states for the benefit of the member states. As explained in the preceding sections, there were research institutions in agriculture, livestock, fisheries, industry, and health research established in these states. However, after the demise of the EAC in 1977, all three member states run research institutions separately. Under the new established EAC, there are several research and scientific institutions, which are run jointly for the mutual benefit of the six member states. The community's scientific and research institutions include the Civil Aviation Safety and Security Oversight Agency (CASSOA), the East African Development Bank (EADB), the East African Health Research Commission (EAHRC), the East African Kiswahili Commission (EAKC), the East African Science and Technology Commission (EASTECO), the Inter-University Council for East Africa (IUCEA), the Lake Victoria Basin Commission (LVBC), and the Lake Victoria Fisheries Organization (LVFO) (EAC, 2018b)

2.4.1 The East African Science and Technology Commission (EASTECO)

The East African Science and Technology Commission (EASTECO) is one of the arms of the EAC. It was established in 2015 to promote and coordinate the development, and application of science and technology to support regional integration and social economic development of the partner states (EASTECO, 2018). The headquarters of EASTECO is in Kigali, Rwanda. Some of the partner states have already established science and technology commissions or councils as in the Tanzanian Commission for Science and Technology (COSTECH), the Kenyan National Commission for Science, Technology and Innovation (NACOSTI), the Rwandan National Commission for Science and Technology (NCST), and the Ugandan National Council for Science and Technology (UNCST) (EASTECO, 2018).

EASTECO, with the mandate to promote and coordinating all matters pertaining to science, technology and innovation in the region, has a large role to play to push forward the development agenda through harnessing science and technology in the community. The institution also is mandated to coordinate the formulation of harmonized science and technology policy, geared to solve common challenges in the Eastern Africa region. EASTECO is a good platform to initiate and develop a joint research agenda for all the member states. Through this institution, the scientific communities, policymakers, key stakeholders and the public in the member states could share scientific knowledge, products and services from R&D institutions for the development of the member states. It is anticipated that EASTECO shall stir up and stimulate investment and performance of scientific communities, and R&D institutions at the national and regional levels for the social wellbeing of the partner states. The establishment of EASTECO marked a new episode in the history of science and technology in the East African Community.

2.4.2 The East African Health Research Commission (EAHRC)

The EAHRC is another organisation that was established to facilitate the mandate of the EAC to improve the health and welfare of the people of the partner states. Its headquarters are in Arusha, Tanzania. The EAHRC is the principal advisory organ to the EAC on health R&D (EAC, 2018c). The EAHRC discharges its mandates through advising the East African Community upon all matters regarding health, and health-related research, and findings that are essential for knowledge creation, technological development, health policy formulation, practice, health services, and so forth (EAC, 2018c). As part of scientific knowledge dissemination, the EAHRC has established the EAC regional health research journal, the East African Health Research Journal (EAHRJ) (EAC, 2018c).

The close interaction of the East African partner states and the people socially, economically and politically should be maintained and strengthened through different mechanisms, including improved health services delivery and prevention of transboundary diseases. Through the EAHRC, it is anticipated that the research collaborations and joint health policy formulation will strengthen scientific communities, as well as the welfare of the people in general. For instance, the EAHRC facilitated the harmonisation of several health policies, and human and animal medicine regulations within the region through the Food and Drugs Authorities of the partner states.

2.4.3 The Inter-University Council for East Africa (IUCEA)

The IUCEA is an organisation of the EAC, and is charged with the coordination and cooperation of universities in East African partner states. IUCEA also promotes internationally comparable higher education standards and systems for sustainable regional development. Its headquarters are in Kampala, Uganda (IUCEA, 2018). The IUCEA is also mandated to advise the EAC member states on higher education matters, and to contribute towards meeting national and regional developmental goals, and build adequate human resources capacity in all fields of science (IUCEA, 2018).

The interaction and cooperation of higher education in East Africa started since the British colonial administration, when Makerere University College was the only higher education institution in the region. Makerere University College was admitting students from Kenya, the then Tanganyika, and Zanzibar in East Africa, as well as from the then Rhodesia and Nyasaland in central and southern Africa, which are now Malawi, Zambia and Zimbabwe (IUCEA, 2018). In 1963, the University of East Africa was established with three constituent colleges, namely the University College of Nairobi, Makerere University College and the Dar es Salaam University College (UDSM, 2017). IUCEA (2018) notes that the IUCEA was one of the surviving institutions of the former East African Community, which collapsed in 1977.

2.5 Historical cooperation between Tanzania and Sweden

Tanzania and Sweden have a long history of bilateral cooperation before Tanzanian independence in 1961. The Tanganyika National Union (TANU), the political party that struggled for Tanzanian independence, and the Swedish Social Democratic Party, the ruling party then in Sweden, had very strong ties based on the socialism ideology and philosophy of both political parties. A Swedish missionary teacher and politician, Barbro Johannson, who immigrated to Tanzania in 1946, played a central role in the initiation and stimulation of the bilateral cooperation between Tanzania and Sweden. Barbro Johansson, or "Mama Barbro", served as a missionary and played a vital role in the founding of the Lutheran Church in the lake zone of Tanzania, as well as the establishment of the Evangelical Lutheran Church in Tanzania in 1963 (Sundby, 1977:11).

Mama Barbro also rebuilt and ran a girls' school at Kashasha, in Bukoba, the lake zone of Tanzania. According to Johasson (1977:144), she became a Tanzanian citizen in 1962 and in the same year, she was elected as a member of parliament representing the Mwanza constituency. She also served as a board member of the University of Dar es Salaam, as well as the advisor to the Tanzanian ambassador to the Scandinavian countries. Mama Barbro and the first President of Tanzania, Julius Nyerere, were close friends, both as teachers and politicians.

> Barbro and I first met in the mid-fifties. But when, as President of TANU, I first visited Bukoba, our supporters knew her and were happy to take me to meet her. Later it became quite natural for TANU to ask her to stand for the Legislative Council (Nyerere, 1977).

President Nyerere, after participation in the constitutional conference in London in 1960, made a private visit to Sweden, following the invitation from Barbro Johansson who introduced him to the political leaders and the former Prime Ministers of Sweden, Mr. Tage Erlander and Mr. Olof Palme, and many others (Mhina, 1977). The friendly relationship and cooperation between Tanzania and Sweden started that evening.

> For those of us who have had the pleasure of meeting Barbro Johansson, it is very inspiring to talk to her and invigorating to work with her. She is a great Swede and Tanzanian. Her work is very much valued and appreciated both in Tanzania and in Sweden (Mhina, 1977:10).

Nyerere (1977) noted that Barbro did different jobs. She worked as a secondary school headmistress, she did adult education, she worked in the Tanzanian Embassies in the Scandinavian countries, she acted as liaison between many Tanzanian and Scandinavian groups, which were working together for the development of our country, and she served on numerous special committees of the party, the government and the church (Nyerere, 1977).

Few years after Tanzanian independence, the bilateral cooperation between Tanzania and Sweden through the Swedish International Development Cooperation Agency (Sida), and the Swedish Agency for Research Cooperation with Developing Countries (SAREC), involved several national projects, including the construction of the Kidatu Hydro Power Plant, the establishment of Small Industries Development Organization (SIDO), and the impact assessment of the Stigler's Gorge Hydro Power Plant (Mafunda, 2017). The first SAREC support for Tanzanian research dates back to 1977 (Gaillard et al., 2002). Sweden also, in collaboration with other Scandinavian countries, supported the construction of Kibaha Education and Health Centre (Simensen, 2010:58; Mafunda, 2017).

> Tanzania was one of the four African countries which in 1966 were selected as priority countries for Swedish development assistance, eventually becoming the principal recipient of Swedish bilateral aid in the world. As of 30 June 1995, a total of 20.3 billion SEK had been disbursed to Tanzania (Sellström, 2003:82).

For decades, Sweden considered Tanzania as a desired country to which to provide support (Elgström, 1999:116).

Figure 2.7: Mwalimu Julius Nyerere with Mama Barbro Johansson

Figure 2.8: Mwalimu Julius Nyerere with Mama Barbro Johansson

Source.https://www.google.co.za/search?q=Barbo+johansson+and+nyerere&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjBkb_Tn9_ZAhUOvFkKHcZYABsQ_AUICigB&biw=1920&bih=960#imgrc=QMrGBZXVrFW-TM:&spf=1520598721801

2.5.1 Research cooperation between Tanzania and Sweden

In 1977, Sweden through SAREC, began to support Tanzania through the Tanzania National Scientific Research Council (UTAFITI), which is the precursor of the Tanzania Commission for Science and

Technology (UDSM, 2017b). Tanzania is one of the very first targeted and recipient country of SAREC. In 1977, through the SAREC support, the Director of Library at the Royal Institute of Technology, Dr. Stephan Schwarz and Roland Hjerppe visited Tanzania at the Tanzania National Scientific Research Council to investigate the needs and establishment of research information and documentation services (Hjerppe, 1979:5). The mission of Swedish expatriates eventually initiated the establishment of the Tanzanian Research Information Services (TANRIS) with the Swedish government support.

The TANRIS managed to collect scientific and information materials from R&D institutions, including human and financial resources, research infrastructures, research outputs, available R&D institutions and centres in the country (TNSRC, 1980). Steadily, the bilateral cooperation extended to develop and strengthen institutional capacity to COSTECH and other R&D institutions, through the training of scientific staff, provision of research grants and research infrastructure development.

UDSM (2017b) notes that Sida's research support to the higher learning institutions in Tanzania started in 1995 at the UDSM, by supporting the marine science programme. From 1995 to 1997, Sida's assistance was more focused on the specific departments and units at the University. The establishment of the Directorate of Research and Publications in 1998, is the pivotal achievement in the coordination of research and innovation activities at the UDSM (Sida, 2017; UDSM,2017b). Thereafter, the cooperation and support approach was directed towards the strengthening of the institutional research capacity of the whole university. The bilateral research cooperation between the UDSM and Sweden benefited a wide range of research disciplines including biomedicine, archaeology, physics, renewable energy, ICT, water and sanitation, mathematics, natural resources management, climate change, to languages and statistics (Sida, 2017).

The UDSM is the biggest beneficiary for research and innovation support from Sida, amounting to about SEK 458.3 million, equivalent to Tanzanian Shillings 119 billion, which financed a total of 57 research and innovation projects in four different phases (UDSM, 2017b).

In 2017, Tanzania and Sweden commemorated 40 years of bilateral research cooperation (1977–2017) through workshops and exhibitions show casing the research and innovation outputs. According to the Swedish Ambassador to Tanzania, Ms Katarina Rangnitt, among other things, the research cooperation has also increased the understanding of tropical diseases among Swedish researchers (Rangnitt, 2017).

According to Sida (2017), between 2015 and 2020, the Swedish government has devoted 336 million SEK (USD 41 million) to support Tanzanian research and development programmes, which are implemented by COSTECH, UDSM, Muhimbili University of Health and Allied Science (MUHAS), and Ardhi University. Generally, the development and strengthened research and institutional capacity in the Tanzanian R&D institutions represented a major cornerstone of the bilateral cooperation between the two countries.

2.5.2 Research and innovation capacity support

The forty years of the research cooperation between Tanzania and Sweden has been fruitful to individual researchers, as well to the institutions from both countries. As Rangnitt (2017) says, Swedish researchers gained good knowledge about tropical diseases through bilateral cooperation.

The joint HIV and tuberculosis research cooperation between MUHAS (the then Muhimbili Medical School of University of Dar es Salaam), and the Karolinska Institute started in 1986. The joint Swedish supported programme introduced the first HIV test kits in Tanzania to investigate the magnitude of the disease. It was revealed as a 20% prevalence in the study conducted in Dar es Salaam, and Pwani and Kagera regions (Sida, 2017). The study saved thousands of lives through policy changes, institutions of guidelines and control programmes of HIV.

The Swedish research collaboration at MUHAS, the European & Developing Countries Clinical Trials Partnership supported the HIV vaccine trial project in Tanzania and Mozambique and brought together researchers from several countries in the world including Tanzania, Sweden, Mozambique, Germany, Switzerland and the United Kingdom (EDCTP, 2013). The research collaboration resulted in the capacity building at the institutions and the collaborating scientists in this area of the vaccine trial for the HIV pandemic diseases. Additionally, under the Sweden research support, MUHAS also produced over 90 scientific publication outputs, which contributed to the formulation of policies and regulations in the control of malaria (Sida, 2017), one of the top three important diseases in the country.

Sida's evaluation report notes that Sida funding support for Tanzanian counterparts became central for EU-Africa collaboration, whereby two large research projects worth 3.5 and 5.5 million Euros received funding. The principal investigators were from MUHAS (Sida, 2014:41). “It is highly notable and quite unusual for major European research projects to be led by principal investigators from a developing country” (Sida, 2014:41).For the same generous support from Sida, a researcher at Ardhi University came up with the ground-breaking innovation for purifying water by using a certain plant. The dissemination and uptake of the results could improve water sanitation and control water-borne diseases, especially in the rural areas (Sida, 2017). The bilateral research cooperation also strengthened the institutional capacity of the participating R&D institutions through the sandwiches training programmes which were conducted in Tanzania and Sweden at both master’s and Ph.D. levels. Sida (2017) notes that the research cooperation delivered a total of 216 Ph.D. graduates and 106 were under the study, 686 MSc graduates and 1,921 peer reviewed scientific publications. This is an enormous research and innovation capacity strengthening for a country like Tanzania with a shortage of qualified research workforce.

2.5.3 Research projects grants support

In 1977, Sweden began to support Tanzania through COSTECH (the then Tanzania National Scientific Research Council), with the research project grants during a limited number of years until it was initiated once more in 2009 (Sida,2017). From 2012 to 2015, through the Sida financial support, COSTECH, through the National Funds for Advancement of Science and Technology, supported 28 research projects implemented by different R&D institutions in the country. Additionally, COSTECH will support 20 research projects from 2015–2020 through generous financial support from Sida (COSTECH, 2015a:14). The collaboration has significantly strengthened COSTECH's capacity for positive implementation of its role and increased visibility and credibility of the institution that has attracted other research partners (Sida,2017). Additionally, the data from the International Foundation for Science (IFS), an international NG0 located in Stockholm, partly supported by Sweden through SAREC devoted to support young career scientists in developing countries, shows that between 1974 and 2019, a total number of scientists supported in Tanzania was 118 (22 women and 96 men). Furthermore, data showed that during the same time period (1974-2019), total number of grants awarded in the country was 157 grants (118 first grants + 34 second grants + 5 third grants). The total amount awarded is close to 1 million USD. (IFS, 2019).

2.5.4 Research infrastructure support

The outputs and outcome of Sida research support in the R&D institutions go beyond the research grants and training of scientists. As URT (1999:1) notes, Tanzanian R&D institutions have inadequate research infrastructure for the smooth conduct of research activities. The bilateral collaboration between Sweden and Tanzania has improved research and teaching infrastructure, particularly in the participating R&D institutions. Sida contributed significantly to research infrastructure at MUHAS, particularly e-journal access and library development (Sida, 2014).The government of Tanzania reports on a few examples of research infrastructures support from the collaboration between Tanzania and Sweden through Sida as noted below (URT,2017: COSTECH,2017).

i. The establishment of Mkwawa and Dar es Salaam University Colleges of Education;
ii. Transformation of the Faculty of Commerce into the University of Dar es Salaam Business School (UDBS);
iii. Strengthening of the multi-disciplinary and regional centre of marine science research at IMS in Zanzibar;
iv. Establishment of the National Postdoctoral Research Framework, the National Research Integrity Framework, the National Research and Innovation Monitoring Framework, and 67 innovative clusters to improve products competitiveness through COSTECH; and

v. Establishment of the knowledge management laboratory and e-library at COSTECH.

Generally, for decades Sweden played a huge role in the capacity building of R&D institutions and strengthening of the Tanzanian science system as a whole. It is well noted that the Tanzanian and Swedish bilateral research capacity strengthening is one example of successful North-South research cooperation. However, other Nordiccountries (Norway, Denmark, and Finland in particular), apart from Sweden, make their contribution in the evolution of Tanzanian science, and the strengthening of the R&D system in the country is remarkable and honoured. The Denmark International Development Agency (DANIDA), the Norwegian Agency for Development Cooperation (NORAD) and the Finnish International Development Agency (FINNIDA) in particular, provided significant research support to the country.

Other international research partners which contributed in the strengthening of science and research in Tanzania include the World Bank, UNESCO, Rockefeller, Carnegie, IDRC, and the Department for International Development of the United Kingdom (DfID). Others are the National Research Foundation (NRF) of South Africa, the African Union–New Partnership for Africa's Development (AU-NEPAD), the National Research Foundation (NRF) of the Korean Republic, the Dutch organisation for internationalisation in education (NUFFIC), the United States Aid Development Agency (USAID), the International Development Research Centre (IDRC), the Australian Centre for International Agricultural Research (ACIAR). Other external organizations which played a substantial role in the strengthening of research in the country are the European Union or Commission and the German Government through GTZ (renamed GIZ) and the Deutsche Forshung Gemeinschaft (DFG) (Gaillard et al., 2002).

2.6 Conclusion

The German and British colonial administrations established agriculture, livestock, fisheries, and health R&D institutions in Tanzania in the early 1900s for the colonial administrations economic benefits. During that time, the R&D institutions conducted research to improve agricultural production, productivity, and protection of the health of European settlers in East Africa. The main objective of the veterinary research station established in Mpwapwa by the Germans was to research the tropical animal diseases and specifically rinderpest, east coast fever and trypanosomiasis, which were so prevalent with high mortality during that time. Their core mission was to conduct research on prevention, control, and treatment of the diseases. Also, the main objective for the establishment of the first fisheries R&D institute by the British in Zanzibar was to conduct research on the tropical marine fish to mitigate the shortage of protein in Europe, especially after World War I.

The German and British administrations introduced varieties of tropical plants for their economic benefits during the first and second industrial revolutions in Europe in the 18th and 19th centuries. They established agricultural R&D institutions and agricultural training centres in the country to facilitate good farming practices for food and cash crops to sustain food security and to produce raw materials for their industries in Europe.

During this period sleeping sickness and malaria were the major two diseases of concern for the colonial administrations. These tropical diseases claimed the lives of many people in East Africa, including Tanzania. The first medical research station to be established in Tabora in the western part of the country, was meant for the treatment of and prevention against sleeping sickness. Additionally, the STIFL in Ifakara, was established by the Swiss to conduct research on tropical diseases, particularly malaria and tick-borne disease (relapsing fever), which threatened people's lives during that time. The Swiss objective was to produce sufficient local expertise in drug and vaccine discoveries against the diseases. The research station in Ifakara also provided field sites for young Swiss scientists and researchers on tropical diseases. Through the IHI, the then STIFL, Switzerland became among the top countries in the world in drug and vaccine discoveries against tropical diseases.

It is fair to conclude that the establishment of research institutes in in agriculture, livestock and health by the German, British and Swiss governments were driven more by their own national interests and concerns. The research done at these institutions were funded and conducted first and foremost to produce food security and health care services for nationals of these countries. It is, of course, also true that the establishment of these research institutions would ultimately benefit Tanzania. The joint R&D system established by the British in the three territories before independence, helped to manage R&D institutions and exploit the resources efficiently. The three territories (Tanzania, Kenya, and Uganda) after independence inherited the R&D system, which was established by the colonial masters. The new EAC that was re-established in 2000, has several sectoral joint R&D institutions, which are run for the mutual benefit of the member states. In other words, the colonial administrations significantly shaped the subsequent course of the R&D system in Tanzania and other East African countries.

The Tanzanian government re-established sectoral R&D institutions after the demise of the EAC between 1979 and 1985. Research funding and capacity building for the newly established R&D institutions were the major challenges for the institutions, simply because the country was in a financial crisis in the early 1980s–1990s. This was the beginning of a critical time for most of R&D in the country, and some of them continue to experience constraints in research funding and research infrastructure.

The special focus on the cooperation between Tanzania and Sweden is justified as Sweden, through Sida/SAREC, ISF, and other Swedish institutions, played an enormous role to build the research capacity of the Tanzanian R&D institutions. Sweden, through Sida, supported and continues to support institutional capacity building for several R&D institutions, including COSTECH, UDSM, AU and MUHAS.

However, it is also worth emphasizing that Tanzania's great dependence on Swedish and other foreign funding for R&D in the country meant that local priorities and an emphasis on local funding for the country's scientists suffered as a result.

CHAPTER 3: STI GOVERNANCE AND INSTITUTIONAL LANDSCAPE

3.1 Introduction

The Tanzanian STI system has a solid governance framework, an explicit STI policy framework and a relatively well-articulated set of R&D performing institutions. The agriculture and livestock R&D institutions which were established during colonial administrations, dating back to the early 20th century, have made some important contributions in the production of seed varieties, animal breeds, good agricultural practices, agricultural extension in the country, and so forth (URT, 2012:60). Nevertheless, over the last three decades, after the promulgation of the first science and technology policy and the establishment of COSTECH, the Tanzanian NSI has been underperforming in terms of research output and technology development and transfer.

There are a number of reasons for this poor performance. Firstly, for several years many R&D institutions have had dilapidated equipment, and a shortage of a skilled labour force and research funding. Secondly, the Tanzanian economic crisis and policy reforms under the recommendations from the World Bank and IMF in the 1980s, brought about the economic shift from the government-owned enterprise to the private sector ownership. During this period and for several decades thereafter, there was very little government support for the R&D institutions in the country in terms of research funding. The R&D institutions, as an important component of the national NSI, were inactive and heavily supported by foreign sources. Therefore, the prevailing weak linkage of R&D institutions and other components of the NSI in the country could be attributed to the heavy dependence on foreign research funding. Thirdly, the human resources base, particularly with respect to the science and technology domains, is shrinking and does not meet the increasing demand for well-skilled and qualified scientists in the country. Fourthly, the STI system has been characterised by fragmentation and a sluggish rate of technology transfer from R&D institutions to industry. Restructuring the legal and institutional frameworks is therefore necessary to ensure well-organised technology transfer, as well as stronger linkages between the government, R&D institutions, industry, and the business sector. Tanzania needs a stronger R&D workforce that is reflective of the population, and an STI system that is more responsive to the current societal technological needs (URT, 2012).

In this chapter our discussion first focuses on the governance framework of the Tanzanian science system, followed by a discussion of the development of STI policy frameworks and finally an overview of the main R&D institutions in the country.

3.2. The governance of the Tanzanian science system

The Ministry of Education, Science and Technology (MEST) is charged with matters regarding science and technology in Tanzania. It has the overall responsibility for the formulation of STI policy and supports its implementations. The ministry's involvement in science, technology and innovation matters is through the department of science and technology. As mandated by the policy, ‘The Ministry responsible for research and development will determine science and technology policy orientation and implementable strategies, and from time to time, review the policy and legislation' (URT, 2010:29).

The current science and technology structure in Tanzania is comprised of the following organs: The Planning Commission under the President's Office, MEST, other sectoral ministries, local government authorities, COSTECH and R&D institutions, development partners, Tanzania Investment Centre, the private sector, NGOs and professional organisations (URT, 2010). The Tanzania Commission for Science and Technology (COSTECH) is a parastatal organisation under MEST, which is mandated to coordinate and promote all matters pertaining to science, technology and its application for social-economic development in Tanzania (URT, 1986b:6). The first national science and technology policy of 1986 stipulated the formation of a more responsive national science coordinating body (COSTECH) from UTAFITI, the former national scientific coordinating body which was enacted by the Parliament Act No. 7 of 1986, and became functional in 1988 (URT,1986b). The Commission is the principal advisory organ of government on all matters relating to scientific research and technology development in the country (URT, 1986b:4).

The Commission is the apex body of COSTECH, which is comprised of members of Commissioners who are the heads of different R&D institutions in the country. The Commission holds its meetings on a quarterly basis to discuss the performance and progress of science and technology matters in the country. During the meetings, the Commission also deliberates and decides on sectoral or policy issues presented for the application and advancement and science and technology in the country. According to URT (1986b:6-7), the following are the general functions of the Commission:

i. To advise the government on matters concerning science, technology and innovation;
ii. To make recommendations on the formulation, implementation and review of national research and development policy;
iii. To advise the government on the institutional and legal frameworks on science, technology and innovation matters;
iv. To promote national capacity building in R&D institutions, including training, technology transfer, innovation systems and infrastructure development;
v. To advise the Government on research and development that will encourage the adoption and application of technologies;

vi. To promote public awareness of and participation in R&D technology-related issues;

vii. To promote the cooperation, collaboration and linkages regarding R&D at national, regional and international levels;

viii. To advise the Government on priority setting in sectoral R&D matters;

ix. To advise the Government and multi stakeholders on funding mechanisms for R&D activities;

x. To encourage multi-stakeholders' partnership participation in the development and application of STI matters for social-economic development of the country.

The function of the Commission is discharged through the R&D advisory committees, which function as the "think tank" for various sectors, and is coordinated by the Secretariat (employed staff members) of the Commission. The R&D advisory committees are the technical organs of the Commission. The committees are accountable for all scientific and technological research in the country and advise on all matters pertaining to research policy, research priorities, allocation of research funds, research coordination and extension, R&D human resource development, and national and international cooperation (URT, 1986b). The members of R&D advisory committees are selected from various R&D institutions, representatives from the government and private sectors, which relate to research and development. The Commission has 10 sectoral R&D advisory committees as listed below:

i. Agriculture and Livestock
ii. Natural Resources
iii. Industry and Energy
iv. Public Health and Medical Research
v. Environmental Research
vi. Basic Sciences
vii. Social Sciences
viii. Development and Transfer of Technology
ix. Biotechnology

All R&D institutions in Tanzania are affiliated to COSTECH. R&D institutions were formed on a sectoral basis, ranging from agriculture, livestock, fisheries, health, energy, natural resources, and engineering, and so forth. According to URT (1986b:10), section 14 (4) of the COSTECH Act No. 7 of 1986 stipulates the formation of sectoral research and development advisory committees to advise COSTECH on policy issues and matters related to science and technology. The R&D advisory committees meet twice a year to deliberate and decide on sectoral science and technology matters.

The Part V of the COSTECH Act specifies the formation of centralised research funding instrument known as the National Funds for Advancement of Science and Technology (NFAST), for the purpose of funding scientific programmes and activities in the country (URT, 1986a:16). Therefore, the

Commission through NFAST, also provides grants for supporting research infrastructure, research projects and capacity building of scientists in R&D institutions, and other related scientific endeavours in the country. The fund was inaugurated in July 1995 and operates under the NFAST committee members who are appointed by the Minister responsible for Science and Technology (Kohi, 2000:97). The NFAST committee holds quarterly meetings to discuss and deliberate on successful projects and other related research funding matters. The sources of NFAST funding are the government, development partners, individuals, private organisations, public organisations, and so forth.

The Tanzania Award for Scientific and Technological Achievement (TASTA) Committee is another standing organ of the Commission, which is mandated to evaluate and make recommendations for an award for ground-breaking and outstanding achievements of individual scientists or R&D institutions in the country. The TASTA Committee was established in 1980 and the Minister responsible for science and technology appoints the committee members (Kohi, 2000:97).

The National Research Registration Committee is another standing mechanism of the Commission, which is responsible for the evaluation and securitisation of the foreign research proposals before they are implemented in the country. The Committee is comprised of members from the government and security bodies of the country. The Committee holds its meetings on a quarterly basis every year.

Parliament is the top level of the STI governance in the country, and has the main role to approve the budget allocation from the government and state organisations. Apart from the role to approve the annual budget, Parliament has several standing committees, which follow up and verify planned budget and activities. For instance, STI matters fall under the infrastructure development committee. The committee deals with several matters apart from STI. The second level of the Tanzanian NSI governance is the government, which includes the Cabinet, the Planning Commission, MEST, the Ministry of Finance and other government ministries. The main role of the government on the NSI is STI funding and formulation of science and technology policies, which are conducive towards the advancement of science and technology for the social-economic development of the country.

The R&D institutions in the country (higher education and research institutions) have the role of producing skilled human resources, knowledge generation, and the production of technologies. The R&D institutions are funded through both parliamentary grants and self-research projects through competitive calls from the government and foreign sources. The private sector forms a significant component of the Tanzanian NSI. The private sector is comprised of many players, including big private companies, SMEs, farmers, and entrepreneurs. The private sector is the intermediate consumer of the science and technology outputs from R&D institutions. The final consumers of the products, services, and processes from research outputs are the markets (local, regional or international markets). The majority of produced products, processes and services from R&D institutions and industries in the country are not demand driven. This is one of the weaknesses in the national NSI, as Figure 3.1 below displays.

In the big picture, the Tanzanian NSI has some elements similar to other NSI, like the one developed by Arnold and Kuhlmann (2001). All frameworks have the key components of NSI (STI governance, R&D performers, funding and private sectors). Nevertheless, an NSI of a country is normally a complex interaction of webs of many elements. A country needs to have a customised NSI to suite its context with the selection of the right and relevant number of indicators. A "healthy" NSI should have the right, relevant and well-defined science and technology indicators for the monitoring and evaluation of the system. The development of a common understanding of the innovation process by players is essential and appropriate for an effective NSI. The Tanzanian NSI has no well-defined science and technology indicators, which are known by all-important key players of the NSI.

Most of research projects conducted in the country are not demand driven, but instead, are done for the sake of curiosity and publications (URT, 2012:67). The private sector is still at the infant stage, which brought about an insignificant level of investment into R&D. This means educational and industrial systems in the country are not responsive to the societal needs to solve prevailing challenges. Additionally, the country lacks a suitable regulatory environment and funding to support the NSI (financial support, taxation, incentives, etc.)

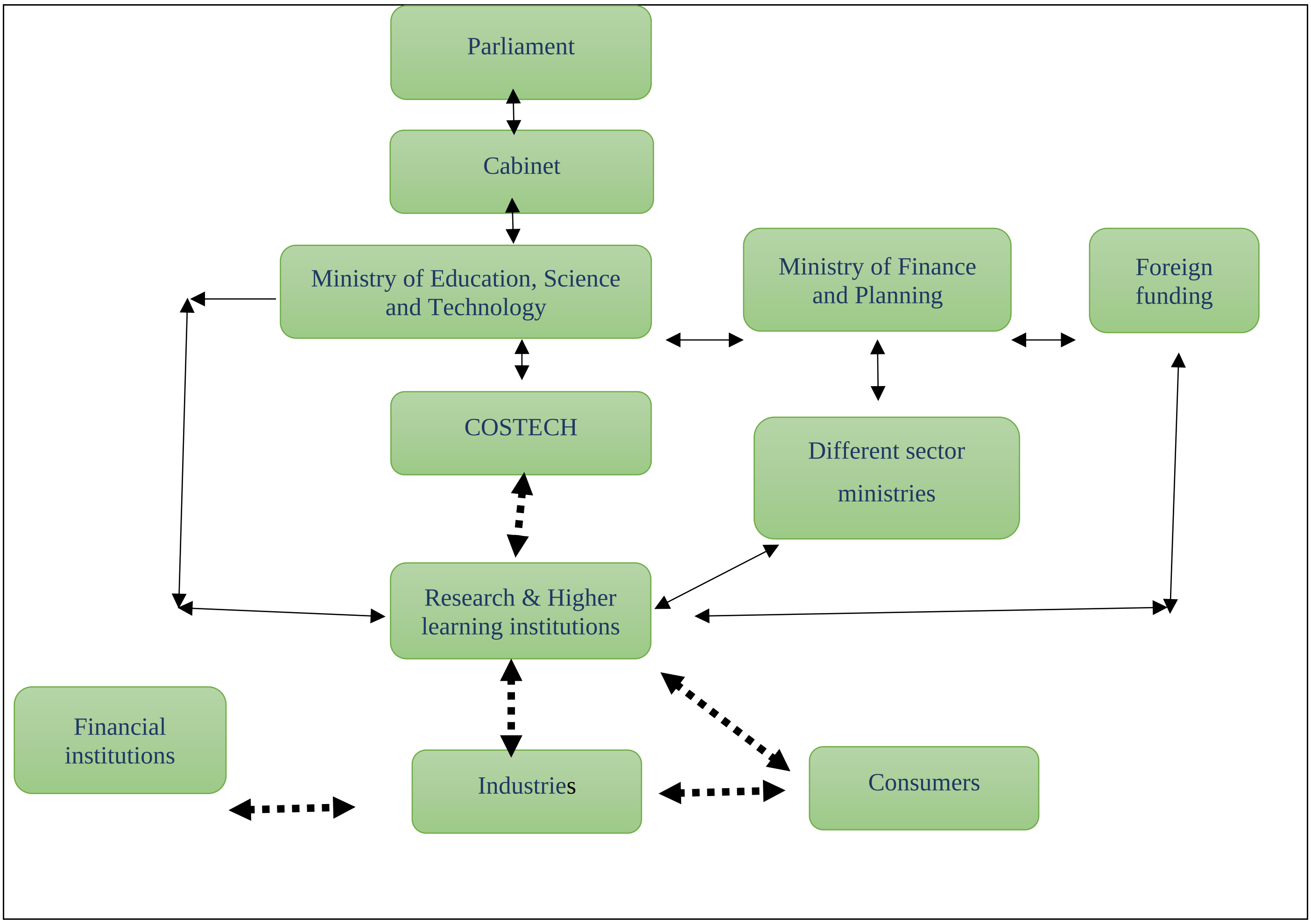

Figure 3.1: Institutional landscape framework of the Tanzanian STI

The current Tanzanian National System of Innovation does not perform the required functions to achieve social economic growth through science, technology, and innovation. For instance, COSTECH as the government organ responsible for coordination and promotion of science, technology, and innovation in the country, does not have a full mandate for the R&D institutions. According to the Act no. 7 of 1986, which established COSTECH, it stipulates that:

> Notwithstanding the provisions of any Act, establishing National Research and Development Institutions, but subject to the provisions of this Act, with effect from the date of commencement of this Act, all the institutions enlisted in the Second Schedule to this Act shall be affiliated to the Commission (URT, 1986b:7).

From the Act, this means all R&D institutions should have a direct affiliation to COSTECH. However, the mentioned R&D institutions were also established by their Act, fall under and report to different parent ministries. In fact, this brings about challenges when it comes to STI data collection, dissemination of research outputs, conducted research, ongoing research programmes and so forth. The existing weak mechanism for integrating and coordinating research activities that are under different ministries is one of the rationales for the review of the Tanzania National System of Innovation (URT, 2012:3). It was also found that COSTECH could not promote, coordinate and at the same time play an advisory role to the government on all matters pertaining to science and technology. It is a conflict of interest. The Commission could not be the player and the referee at the same time. Additionally, the private sector, as a key player in the Tanzanian NSI, does not actively participate in science and technology for the social-economic development of the country. The weak support on the IPR issue and commercialisation of research outputs are among the challenges in Tanzania.

In 2012, a report on the review of the NSI was completed, followed by an external review report in 2013 and the synthesis report in 2014. The draft of the new Tanzania NSI is currently still at the cabinet level for final decision and publication. The Tanzania Development Vision 2025 and science and technology policy identified important productive sectors of the economy to enable Tanzania to become a middle-income country by the year 2025. These productive sectors are the following categories: i) agriculture, ii) industry and construction, iii) tourism, and iv) manufacturing.

The agricultural sector remains the main employer in the country. In spite of the huge proportion of the population that derive their livelihoods from agriculture (75%), the contribution of the sector to GDP is not impressive, with only 28% contribution to the economy. Agriculture is growing at 3% annually, which is low compared with other sectors. The performance of the Tanzanian agriculture sector is low, leading to poor productivity, simply because of the application of poor agricultural technologies. In spite of the efforts of government, through the Ministry of Agriculture, to establish the agricultural inputs subsidy scheme, still a small proportion of farmers access agricultural inputs (seeds and fertilizer). Sometimes the inputs arrive off-season. The majority of farmers use traditional farming practices over decades, which result in low yields. As URT (2012:48) notes, 70% of the land in the country is cultivated by hand hoe, 20% ox-plough, while tractors cultivate only 10%. The country for several decades has prioritised the sector by running several programmes to boost the sector, but still its performance is low. There is also the issue of inadequate agricultural extension services, the poor marketing structure of agricultural products and low investment in the agro-processing industry. For a well-functioning and effective NSI, the country needs to strategise the sector and makes sure all key actors interact to optimise the productivity of the sector.

According to the external review report of the Tanzanian NSI, the industry and construction sector contributes about 25% to the national GDP (URT, 2013:26). The manufacturing sub-sector is the prominent productive economic sub-sector in the industry. During colonial administration, the agricultural sector in the country was given high priority in which food and cash crops (sisal, cotton, tea) were grown. The cash crops were produced to feed industries in Europe. After independence, the major manufacturing sector and foreign currency generator in Tanzania was agro-processing industries. The country has been putting in efforts to vitalise the sector since independence. The manufacturing sub-sector has huge untapped potential to contribute to the national economic growth. According to URT and UNIDO (2012), the Tanzanian industrial competitive report shows that in 2010 the country had high-tech (HT) commodities of 2%, medium tech (MT) of 11%, low tech (LT) of 17%, while 69% is resource based (RB) export. From the statistics, it is evident that the sub-sector could be utilised to build the national economy. The country has the opportunity to optimise the contribution of the sub-sector through the establishment of agro-processing industries by value addition to the raw materials from the agricultural sector.

The Tanzania Development Vision 2025 and the fifth government, under President Dr. John Joseph Magufuli, put emphasis on becoming a middle-income country through industrialisation. Therefore, light agro-processing industries could be a strategy as a short-term plan to achieve economic growth by 2025, simply because it does not need high technology investment. Investment on high- and medium-technologies could be used in mid- and long-term strategies and programmes. Revitalising agro-processing manufacturing industries in Tanzania will create diversified employment opportunities and boost the agricultural sector. The manufacturing sub sector needs to be placed well in the NSI so that different key actors could complement each other and drive positive national economic growth.

3.3 Tanzanian STI policy

Since its independence, several strategic policies and programmes to achieve economic independence have guided Tanzanian economic history. The promulgation of the Tanzania National Scientific Research Council (UTAFITI) that was enacted by the Act No. 57 of 1968 was an important step in the coordination and promotion of science and technology in the country. The basic industrial strategy of 1976 promoted the importance and the role of an industrial-based economy for the social-economic transformation the country to attain self-reliance (Kohi, 2000:81). In 1981, the country launched the National Economic Survival Programme (NESP), the economic recovery initiative following the fall of the Tanzanian GDP, which occurred in the late 1970s. One year later, the government instituted the NESP, which was followed by the three years' structural adjustment programme (SAP), from 1982 to 1985, to absorb the economic shock in the country (URT, 1996).

In 1986, the government again launched the economic recovery programme (ERP), based on IMF agreements for the purpose of stimulating positive economic growth per capita, and reduce the inflation rate. This was followed by the economic and social adjustment programme (ESAP) with the World Bank in 1991 (Hyden & Karlstrom, 1993). These measures imposed by the World Bank and IMF brought about significant transformation and amendment for sectoral policies in the country, including the Tanzanian science and technology policy which was promulgated in 1986 (URT, 1996). The first Tanzanian science and technology policy of 1986 stipulated the formation of COSTECH from UTAFITI, which was enacted by the Parliament Act No. 7 of 1986 and became operational in 1988. The national research and development policy of 2010 is the current S&T policy in use in the country. However, the policy is under review to accommodate an innovation component that was not imbedded in the current policy.

3.3.1 The global and African initiatives towards the formulation of science and technology policy in Tanzania

It is well known and recognised that the first initiative in the recognition of science and technology as an assessable tool for social-economic development was spearheaded by the United Nations Educational, Scientific and Cultural Organization (UNESCO). UNESCO initiated and organised the first United Nations Conference on the Application of Science and Technology (UNCAST) for the benefit of the less-developed countries. According to COSTECH (2005), Tanzania was one of the African countries that attended the United Nations Conference, which took place in Geneva, Switzerland from 4th–20th February, 1963.

The UNCAST Conference discussed and agreed upon several issues related to the application of science and technology for social-economic development. Countries made a number of recommendations to assist with the implementation of science and technology as a tool for development. According to the United States report (1963), the conference drafted three recommendations for the organisation and planning of scientific and technological policies. These recommendations were:

- Establishment of an organ such as a national research council in each country to make plans in consultation with the highest governmental levels;
- Assurance of scientific guidance in the implementation of policy;
- Establishment of modern universities, based on the fundamental sciences to train people, not only in the traditional professions, but also as research scientists.

The Tanzania National Scientific Research Council (UTAFITI) was the first national effort to coordinate research and development activities, and was established in 1968 (Gaillard, 2003:319). The Tanzania Parliamentary Act No. 51 established the council in October 1968 and then inaugurated it on 25th June 1972. Part II and section 5 of the Act stipulated the functions of the Council and gave a mandate to UTAFITI regarding research coordination in the United Republic of Tanzania and the advisor to the government on research priority areas, and the allocation and utilisation of research funds according to the priorities set out (URT, 1968:2). The establishment of an organ responsible for planning and coordinating research activities and provide policy recommendations to the government was a milestone and a step forward for the science system of Tanzania. The mandate of UTAFITI was to coordinate research institutions which were not under the coordination of the East Africa management and administration (Kohi, 2000:91).

To acknowledge the role of science and technology in social-economic development, the Tanzanian minister responsible for science and technology and his delegation attended the first Regional Conference of Ministers Responsible for Application of Science and Technology in Africa (CASTAFRICA 1), which was held from 20th–31st January, 1974 in Dakar, Senegal. CASTAFRICA 1 was organised by UNESCO, with the cooperation of the Economic Commission for Africa and the Organisation of African Unity (UNESCO, 1974:9). According to the UNESCO report, the objective of CASTAFRICA 1 conference was to enable the African member states to exchange information on their national science and technology policies, improve the application of these policies and the execution of research activities. The conference also intended to promote scientific and technological research, which is vital for the social-economic development of any nation, stimulate technological innovations with a view to increase productivity, examine the role of science and technology in government activity as a whole, and foster international co-operation to meet these goals.

During the CASTAFRICA 1, Tanzania had already established the Tanzania National Scientific Research Council in 1968, responsible for the coordination, promotion and popularisation of science and technology, so it was an important platform for sharing with and learning from other countries. According to UNESCO (1974:15), to realise the outcome of science and technology applications, the conference drafted several recommendations including: the African member states to increase financial resources for research and development (R&D) activities to up to 1% of the GDP before 1980 as proposed by UNACAST in the World Plan of Action. The conference recommended to UNESCO to establish a special fund for African R&D development for the strengthening of human resources, R&D infrastructure, and scientific research. For Tanzania, to participate in this important science and technology conference, was a stepping stone to establish the science and technology policy in 1986, and other institutional and legal frameworks.

In September 1975, UTAFITI organised a seminar on project preparation for researchers from different R&D institutions (TNSRC, 1976:5). The seminar recommended an urgent call for the formulation of the national science and technology policy to act as a guideline for R&D institutions. The Tanzania National Scientific Research Council also organised a closed national seminar in December 1977, held in Arusha, to discuss the application of science and technology for the social-economic development of the country (TNSRC, 1978:4). The closed seminar was followed by an open national seminar on science and technology for development, which was held in Dar es Salaam in January 1978.

Tanzania also organised a symposium on African goals and aspirations in the United Nations conference on science and technology for development, which was held in Arusha in February 1978. The symposium brought together some prominent African scientists and policymakers to discuss the utilisation of science and technology for social-economic development (TNSRC, 1978:4). All series of seminars were also intended for the preparation of the national paper that was presented during the United Nations Conference on Science and Technology for Development (UNCSTD), which took place in Vienna in August 1979. The second open national seminar on S&T for development was also held in Arusha in 1980 for more discussion on the application of science for development after the Vienna conference. These national and international efforts together accelerated the formulation of the first national science and technology policy and the strengthening of institutional and legal frameworks of the science system in Tanzania.

Tanzania attended the UNCSTD. The conference took place in Vienna from the 20th–31st August, 1979, and set up the Vienna Plan of Action (VPA) in 1979 (TNSRC, 1980). The conference came up with several resolutions on matters pertaining to science and technology for social-economic development. The conference emphasised the urgent need to establish and strengthen science and technology capacity in developing countries, to reduce the gap between industrialised and developing countries (UN, 1979). The conference also recognised the roles of intergovernmental and non-government organisations as the key players for the implementation of science and technology to bring about social-economic development. The VPA on science and technology for development was an important output of the conference. The programme to ensure the full participation of women in science and technology, was also established. Through this important conference, the Tanzanian government also had the opportunity to learn more about science and technology for development.

African members of states learned an important lesson from the UNESCO initiatives on science and technology as a key driver of social-economic development. The Organization of African Unity (OAU) revived the mission by holding a series of meetings in Lagos and Monrovia, after which, finally in 1980, the declaration on the STI milestones was made. On 29th April in 1980, history was made on the African continent by African leaders who adopted the "Lagos Plan of Action for economic development of Africa: 1980–2000" (OAU, 1980). In adopting the Lagos Plan of Action (LPA), all African governments acknowledged the efforts which are required by African countries to implement the plan to realise the outcomes. Among other things, the OAU, through the LPA, stipulated that African member states have adopted measures to ensure the coordination, promotion, and application of science and technology in spearheading development in agriculture; health, transport, industry, education, manpower development, urban development, housing, and energy.

The OAU (1980) encouraged the member states to promote science and technology for national and regional development. All member states were required to organise annual scientific conferences and exhibitions to showcase research outputs and bring together scientific communities, to organise interregional science and technology forums to accelerate technology transfer, and exchange scientific knowledge. According to the LPA, African member states were required to formulate a national policy on science and technology, and this needed to be incorporated into the overall national development plan. After the Lagos meeting, Tanzania took several steps to formulate a science and technology policy.

3.3.2 Formulation of the first Tanzanian science and technology (S&T) policy in 1986

Tanzania is acclaimed as being the second country in sub-Saharan Africa, after Ethiopia, to formulate a brief and clear National Science and Technology Policy (Kohi, 2000: 82). In 1984, the Tanzanian government played its role in the implementation of the LPA, and recommendations from national seminars by drafting the S&T policy document and holding a series of national meetings and workshops taking on board key stakeholders to discuss the formulation of the Science and Technology Policy (Diyamett et al., 2010:15; TNSRC, 1976:5). Following these initiatives, the first S&T policy was approved and became operational in 1986. The S&T policy was then reviewed in 1996 as the result of the economic structural adjustment programmes in Tanzania, which took place in the 1990s. During the formation of the first national science and technology policy, macro-economic means of production was based on state ownership. The structural economic adjustment changed national policies to accommodate privatisation and trade liberalisation (URT, 1996).

The Tanzanian science and technology policy of 1986 spelled out the establishment of a dedicated ministry to deal with science and technology and the formation of COSTECH with the mandate of S&T coordination, setting of national research priority areas, advisory and S&T policy formulation (URT, 1986a). COSTECH was established in 1986 by the Act of the Parliament No. 7, as a successor to UTAFITI, which repealed and replaced the Act of the Parliament No. 51 of 1968 (URT, 1986b:5). In 1990, the Ministry of Science, Technology and Higher Education was established and charged with all matters related to science and technology and to coordinate S&T policy implementation. This was an important milestone in the history of science and technology in Tanzania.

Additionally, both the Tanzanian science and technology policy of 1986 and the COSTECH Act no. 7 of 1986, part V sections 23–26, stipulated the formation of NFAST as an instrument under COSTECH for supporting research activities in the country. It elaborates that the sources of funds of NFAST are the budgetary allocations from the government and the public and private development partners. This research funding instrument was an important step in supporting research and innovation projects for the national benefit. The establishment of the national research funding mechanism is a milestone that needs to be operationalised by disbursing the required amount of funding, as it was set by the policy.

The Mouton et al. (2015:162) study on the function of the Science Granting Council in 17 sub-Saharan African countries acknowledges that Tanzania has a well-established COSTECH as the framework for funding research and innovation activities in Tanzania. The study establishes that, apart from Tanzania, other sub-Saharan African countries with well-established science granting commissions are South Africa, Kenya, and Zimbabwe. Notwithstanding, budgetary investment in research activities in Tanzania is not catching up to 1% of the GDP, as agreed in the Abuja Declaration. In 2010, the GERD/GDP in Tanzania was 0.38%, while the neighbouring East African countries of Uganda and Kenya had a GERD/GDP ratio of 0.48% and 0.79% respectively (UNESCO, 2015:521).

A policy is a living document that needs regular evaluation and review to suit the prevailing and expected societal needs and desires. The first science and technology policy of Tanzania, after its formulation in 1986, was then reviewed in 1996 to accommodate the global change of trade liberalisation and privatisation of macroeconomic means of production that was previous under state ownership in many countries, including Tanzania. The first S&T policy of 1986 had no science and technology indicators. This became the essence of the first review of the policy in 1996. The reviewed S&T policy of 1996 identified the following indicators for measuring science and technology capacity and capability in the country: size of research and development expenditure, the ratio of research and development manpower to the total labour force in the country, and the ratio of university staff members to the number of students enrolled. Other indicators are the ratio of BSc to MSc and Ph.D. graduates in science and technology, the publication volume in scientific journals, patents, and science and technology working facilities (URT, 1996:57–58).

The reviewed policy was used for about 15 years (1996–2010) when it was then again reviewed and led to the formulation of the National Research and Development Policy of 2010 that is currently in use. According to the URT (1996), the following are highlighted salient features of the National Science and Technology Policy of 1996:

- The allocation of funds for scientific research and technology development (about 1% of GDP by the year 2000;
- The monitoring of importation or acquisition of foreign technology, including its evaluation and selection;
- High level scientific research and technology manpower training, motivation and retention programme, including the provision of attractive terms and conditions of service for scientists and technologists;
- Utilisation of Tanzanian scientists and technologists in consultancies;
- The popularisation of science and technology with the view of inculcating the scientific and technological culture in the society;

- The promotion of professional standards and ethics through support to science academies, professional associations and scientific clubs and other scientific and technological non-governmental organisations;
- The preservation or conservation of the environment or ecosystem in the process of industrialisation of natural resources.

3.3.3 Implementation of the Science and Technology Policy of 1996

The allocation of funds for research activities is one of the crucial ingredients for the implementation of science and technology policy. The first Tanzania S&T policy of 1986 acknowledged the importance of funds allocation for science and development activities by proposing 1.5% of the GDP to be allocated for supporting research and development activities in 1985/86 and the allocation to be raised up to 3.5% of GDP by the year 2000 (URT, 1986a:42). The policy additionally stipulated the establishment of NFAST, which was promulgated in 1995, to enhance the allocation of research funding to meet the desired target. The S&T policy of 1996 decreased the government target to invest in science and technology from 3.5% to 1% of the GDP, as it was stated by the first Tanzania S&T policy of 1986 (URT, 1996:7).

The allocation of enough research funding still remained a challenge over the three decades since the formulation of the first science and technology policy and the establishment of COSTECH in 1986. The most recent UNESCO science report of 2015 showed that Tanzanian investment in R&D was very low at 0.38% (UNESCO, 2015:560). Additionally, several science and technology reports show that a big proportion of research funding in Tanzania comes from donors and hence donors' research agendas are implemented, rather than the national research priorities.

Part IV of the COSTECH Act No. 7 of 1986 also stipulates the establishment of the national Centre for the Development and Transfer of Technology (CDTT) under COSTECH. The major role of the centre was development and transfer of technologies, and the monitoring and evaluation of foreign technologies before importation into the country (URT, 1986b:11). The centre was also intended to advise the government on the appropriate technologies to be developed and transferred to society for the social-economic transformation of the country. In Tanzania, as in any other developing country, it is important to select and monitor the importation of technologies from outside the country to safeguard industrial and technological development. COSTECH established CDTT in 1992 by transforming the then Directorate of Technology Development and Policy (Mbogoma & Mukama, 2001). Notwithstanding, as the results of the national policy changes on trade liberalisation that allowed free-market importation of technology according to one's choice, CDTT did not do much as far as its legal mandate and the functions were concerned.

The Tanzanian science and technology policy of 1996 desired to have a high-level scientific and technology workforce. This was not achieved. According to the World Bank report (2016), Tanzania still faces a shortage of a high-level skilled workforce. The proportion of the Tanzanian population with a tertiary education is 3%, which is low compared to many countries in sub-Saharan Africa (FSDT, 2017). Training and capacity building of a scientific and technological workforce in R&D institutions in Tanzania needs deliberate planning and the allocation of enough financial resources, as stipulated in the S&T policy. However, as pointed out above, financial investment in R&D is still a big challenge for the government.

Offering attractive and motivated conditions for scientists in the R&D institutions in Tanzania also remains a challenge. The situation brings about a brain-drain of senior research personnel from R&D Institutions to non-scientific organisations. According to the findings in the Flagship Universities in Africa, (Ishengoma, 2017), the major factor which causes the brain-drain from the University of Dar es Salaam, is financial income. The report shows that the income of academic staff is far less when compared to members of the parliament, international organisations and other senior positions in the civil service departments in the country.

The national research and development policy realised few research results that were converted into tangible outputs. The policy clearly showed inadequacy in guiding popularisation, uptake, and utilisation of research results. Most of the produced research results from R&D institutions are shelved without being disseminated to the beneficiaries to bring about the impact and social-economic benefit in the country.

One of the key roles of COSTECH is to promote the wide application of technologies with big social-economic impacts and strengthening a science, technology and innovation culture. COSTECH, as the national focal institution mandated to coordinate, promote and popularise science and technology in the country, failed to fulfil its role effectively. However, as shown above, the Commission lacks legal and institutional power over affiliated R&D institutions simply because these R&D institutions are also answerable to their sectoral ministries (UNCTAD, 2003:74). The Commission lacks a proper mechanism and framework for the coordination of science and technology in the country. According to COSTECH (2007:15), "The current system of affiliation is workable on a personal public relations basis but there is nothing to compel the unification into a national science and technology system". The R&D institutions were established by their own Parliamentary Acts and are answerable to individual parent ministries and not to COSTECH, which in turn weakened the affiliation and research coordination. The government should formulate a legal framework for the Commission to discharge its coordinating role effectively in collaboration with stakeholders to realise the potential benefits of science and technology.

3.3.4 Context and implementation of the national R&D policy of 2010

Tanzania is currently implementing the national R&D policy of 2010 as the roadmap for science and technology matters. The rationale for the review of the S&T policy of 1996 and the formulation of the national research and development policy of 2010, was based on a social-economic review of various policies, which appeared in Tanzania in the 1990s, to embrace a liberal social-economic system. These policies focused on the promotion of the private sector to participate in the contribution to the national economy (URT, 2010:8). Additionally, the policy put emphasis on the commercialisation of research products to promote innovation activities in the country, priority setting of the national research agenda and harmonisation of different ministries and institutions which are involved in research activities. However, the policy is under review to accommodate the innovation element in the light of the Tanzania Development Vision 2025.

The revised draft of the policy has been prepared in combination with ongoing reform of the national innovation system. The policy draft is at the cabinet level waiting for approval, and if changes are adopted, COSTECH will be reformed and the new Commission will be called the Tanzania Commission for Science, Technology and Innovation (TCSTI) (UNCTAD, 2015:61).

As stated in the policy document based on the vision and mission, the following are the ten key areas of the national R&D policy of 2010 (URT, 2010:11).

- **i.** Strategic R&D leadership and institutional framework;
- ii. Prioritisation of research areas;
- iii. Enhancement of research capacity in ICT and social-economic disciplines;
- iv. Commercialisation and dissemination of research results;
- v. Human resource development and management;
- vi. Financing of research and development;
- vii. Research ethics and intellectual property rights;
- viii. Collaboration, partnership and networking;
- ix. Regional and international cooperation; and
- x. Cross cutting issues (gender, environment, and occupational risks, e.g. HIV/AIDS).

As pointed out above, the focal areas of the current policy on science and technology matters in Tanzania, several issues that were stated in the previous science and technology policies over the three decades after the first policy of 1986, are still in vain. For instance, the allocation of 3.5% and 1% of the GDP by the government to support research and development activities, as desired by both science and technology policies of 1986 and 1996, is still stated by the current national research and development policy of 2010. The current policy still emphasises the importance of adequate financing of research and development activities by the allocation of funds of not less than 1% of the GDP, since the current status is still far below that target at 0.35%.

The prioritisation of national research areas is of paramount important to ensure that research efforts are geared towards solutions for the commonly identified problems in the country. The current R&D policy, which is used in the country, pointed out the prioritisation of the national research areas after the first version formulated in 1998 and used for 12 years. According to URT (2016b), the current national research agenda for the 2015–2020 period, which is the second series of the national priority areas, was formulated in 2015. The formulation of the second national research priority setting and its periodic review based on the societal needs, is noted as an achievement of the current policy. However, implementation of the national research priority areas requires adequate funding for research activities and well-coordinated R&D institutions, which is still a challenge.

Commercialisation and dissemination of research results are among the challenges facing Tanzanian R&D institutions. According to URT (2010:17), few research results have been commercialised, converted to tangible outputs and disseminated for public consumption. Additionally, the concept of Intellectual Property Right (IPR) is still new to most researchers in the country. The level of technology transfer and commercialisation of research and innovation outputs in Tanzania is still low and the number of patents is insignificant. A weak linkage between R&D institutions and industry leads to the failure of transfer and commercialisation of research outputs. In recent years, COSTECH took several initiatives to create awareness and sensitisation to R&D institutions on the issue of IPR and the importance of commercialisation of research results. TTO is the ‘umbilical cord’ between R&D institutions and industry, which facilitates commercialisation of research outputs.

The strategic R&D leadership and institutional framework is another focal area of the Tanzania R&D policy. The policy identified the inefficiency of R&D coordination and incoherence of institutional frameworks of the R&D system which should be ironed out to enhance the effectiveness and efficiency of R&D performance. In 2017, the government, through COSTECH in collaboration with R&D stakeholders, developed three different R&D institutional frameworks as the guidelines for research management and ethics. The frameworks are the national postdoctoral research framework as a guideline for running postdoctoral research, the national framework for monitoring research and innovation as the harmonised framework that will be used by R&D institutions across the country for the management of research, and the national research integrity framework geared to capacitate R&D institutions to establish institutional ethical review instruments.

Human resource development and management have been acknowledged by the policy as an important key area to be dealt with to ensure availability of well-trained personnel in R&D institutions in the country (URT, 2010:19). The quality and quantity of research production of a country depend on research and innovation capacity of R&D institutions. As detailed and explained in Chapter 3, the total research and development personnel head count (HC) in 2010 in Tanzania was 5788. The number of researchers was 3102, of which 789 (25%) were women and 2015 (65%) researchers were working in the government higher learning institutions (AU-NEPAD, 2014:104). According to the most recent UNESCO science report (2015:542), Tanzania in 2010 had 69 researchers per million inhabitants. Compared to other African countries, these numbers are small: South Africa leads with 818, followed by Senegal with 631, Gabon with 380, Botswana with 344 and Kenya with 318. Therefore, Tanzania needs to design a mechanism deliberately to increase the human resource capacity of its research and innovation in order to tap the potential of science and technology.

Collaboration, partnership, and networking of researchers in the Tanzania R&D institutions are low. The current policy insists on the importance of R&D institutional collaboration in terms of joint research projects and sharing of research infrastructures among institutions URT (2010:23). Several mechanisms are already in place to encourage collaboration of researchers in R&D institutions in the country. For instance, the research calls that are administered by COSTECH encourage inter-institutional applications rather than intra-institutional research teams. The development of research infrastructure is an expensive endeavour that consumes a substantial amount of funds. The mapping of research infrastructure is required to identify research equipment in the R&D institutions country wide and come up with a mechanism for sharing these facilities by all R&D institutions, hence reducing duplication efforts for purchasing expensive research infrastructure. Sharing research infrastructure will also increase networking and the collaboration rate between the R&D institutions in the country. Therefore, COSTECH, as the national research coordinating body, needs to conduct an inventory of all research equipment in the R&D institutions and make the information available to the research stakeholders.

Strengthening of regional and international cooperation of R&D institutions in the country is another key area of the national research and development policy. Tanzanian research cooperation with other countries is important for learning and improving research skills and sharing expertise. Research cooperation with other countries or agencies helps researchers to access modern research infrastructure and build up research excellence among participating partner countries. COSTECH, as the national research coordinating body, mobilised support for research and innovation with partners such as the National Research Foundation (NRF) in South Africa, the Danish International Development Agency (Danida), the Swedish International Development Agency (Sida), and the Department for International Development of the United Kingdom (DfID). The other research partners are the Centre for Scientific and Industrial Research (CSIRO) in India, the NRF in South Korea, the United States Aid Agency (USAID), the African Agricultural Technology Forum (AATF), the Australian Centre for International Agricultural Research (ACIAR), and so forth.

Additionally, COSTECH is one among 15 science councils in Africa that participate in the Science Granting Councils initiatives (SGCI) in sub-Saharan Africa to strengthen national science systems in order to support research and evidence-based policies. The SGCI is a five years' programme (2015-2020) which is funded by NRF South Africa, IDRC and UK DfID. Moreover, individual R&D institutions in Tanzania collaborate with R&D institutions outside the country in order to strengthen research capability. According to Sangeda and Lwoga (2017:73), a 24 years' scientometric study in Tanzania shows that 73% of publications are being co-authored with international research partners. The study further shows that the United States (21.6%) and the United Kingdom (20.2%) are the top countries collaborating with Tanzania. The donor research funding drives the higher international collaboration rate in the country.

3.3.5 Challenges facing implementation of the national research and development policy

Tanzania has had three versions of S&T policies since the promulgation of the first S&T policy of 1986. Currently the country is implementing the national R&D policy which was formulated in 2010, however, the policy is under review to accommodate innovation components and other issues. The following are some challenges that affect the effective implementation of the national R&D policy.

- Inadequate funding to support the implementation of research and development activities is one of the major drawbacks for most of the R&D institutions. The government of Tanzania in 2010 committed to allocating 1% of the GERD/GDP for research activities through COSTECH. The allocation of research funds and disbursement is still not satisfactory. According to the UNESCO report of 2015, in 2010 the GERD was 0.38% of the GDP in Tanzania.
- Commercialisation of research products or innovation in Tanzania is still a challenge. R&D institutions come up with a number of research products, which are not commercialised and do not get to the potential beneficiaries. However, the Parliament Act No. 13 of 2016 that established the Tanzania Agricultural Research Institute (TARI) mandates and gives power to the institute to commercialise agricultural research outputs (e.g. seeds). This will facilitate quick the dissemination of agricultural research results to the beneficiaries
- It was noted that poor quality products and lack of promotion is a major challenge facing Tanzanian industries (Malanga, 2016).The fifth government of Tanzania strives to push the country to become a middle-income country by the year 2025 through an industrialised economy. Therefore, in this era of a free market economy, it is vital for the industries to produce good-quality and competitive products. Additionally, it is important to promote locally produced products and the government to provide incentive schemes to innovators and industries.

- The poor linkage between R&D and industry brings about a low uptake of research products to the market. Initially, R&D institutions were established to develop and transfer technologies to the industries. In the past decades before trade liberalisation, both R&D institutions and industries were under the ownership of the state and the link between the two was substantial (Wangwe et al, 2009). The free market economy and the privatisation of industries and means of production in the 1990s, resulted in the collapse of many industries in the country. During that period of the economic struggle, R&D institutions suffered from insufficient research funding, which led to a decrease in research activities in R&D institutions.
- The Tanzanian researchers head count was far behind South Africa by 12 times, and Kenya by 4 times (AU-NEPAD, 2014). Additionally, the UNESCO science report of 2015 shows that in 2010 the researchers' population per million habitants was 69 for Tanzania, while South Africa and Kenya had 818 and 318 respectively. From the statistics above, it is clear that Tanzania is facing a shortage of research personnel to conduct R&D activities.
- COSTECH, as the focal institution which is mandated to coordinate, promote and popularise science and technology in the country, faces a challenge to fulfil its role effectively and efficiently. There is a weak link between COSTECH and affiliated R&D institutions. R&D institutions are affiliated to COSTECH, but at the same time are answerable to their sectoral ministries. As noted above, the current system of affiliation is not workable on a personal public relations basis, which attributes to inefficient implementation and coordination of research and development policy.

3.4 The R&D institutional landscape

The public and private research institutions are vital elements of the NSI of a country. Both research institutions and universities are knowledge and technology hubs in which products and processes are generated. A well-functioning NSI needs efficient research institutions and universities, which actively interact with other players in the NSI. As it was discussed in the previous chapter, there are few tangible research outputs in the country which are commercially viable. Most of the research findings end up on R&D institution shelves without utilisation and commercialisation.

As discussed in the previous chapters R&D institutions in Tanzania have a long history going back to the German administration in 1902. The agriculture, livestock and health research institutions were among the first R&D institutions to be established in the country during the German and British administrations. The establishment of agriculture R&D institutions during the colonial administrations was mainly geared towards research on commercial crops like cotton, coffee, sisal, tea, and so forth.. In 2017, there were 74 R&D institutions in Tanzania (COSTECH, 2017; TCU, 2017). Out of the 74 institutions, 49 (66%) are higher learning institutions and 25 (34%) are research institutions, as Figure

3.2 below illustrates. The agricultural research institutions are widely distributed over the seven agro-ecological zones in the country, conducting research on specialised crops and livestock production and disease management. The health research institutions are also distributed in all the zones of Tanzania, conducting specialised health research. The other sectoral institutions are the natural resources research institutions, fisheries research institutions, food and nutrition research institutions, social-economic research institutions, and the energy and industry research institutions. The R&D institutions in the country fall under the following categories: (1) higher learning institutions (universities/colleges), (2) public research institutes and centres, (3) private research institutes, and (4) international research institutes.

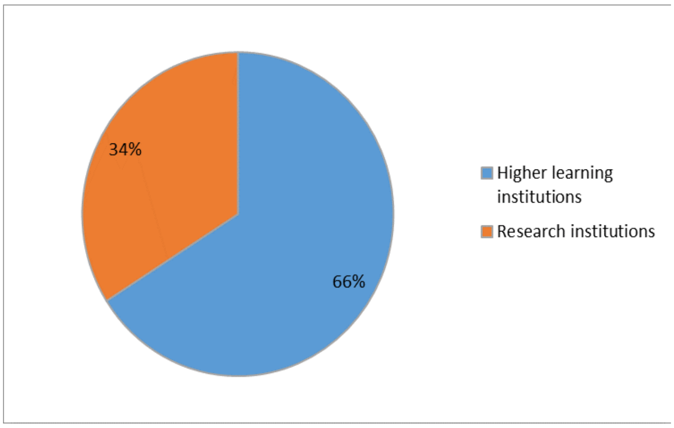

Figure 3.2: Share of higher learning and research institutions in Tanzania

Data Source: Tanzania Commission for Universities (TCU), 2017:COSTECH, 2017.

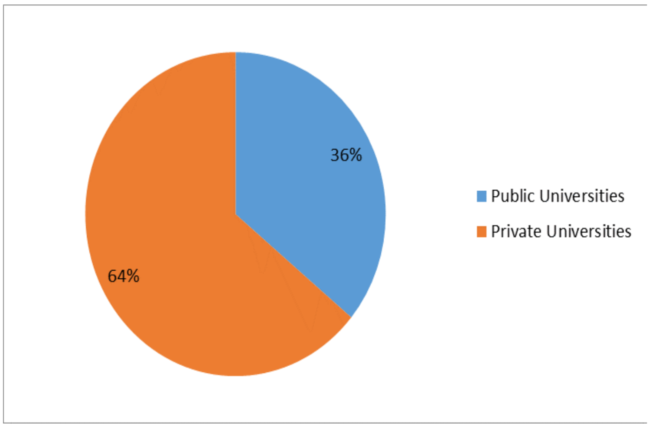

Figure 3.3: Share of public and private universities in Tanzania

Data Source: Tanzania Commission for Universities (TCU), 2017.

3.4.1 Higher education in Tanzania

Tanzania has 33 universities. The majority of them are private universities (21), and only 12 are public institutions (TCU, 2017). However, the public universities enrol the majority of students in the country, due to their size and capacity. Higher learning institutions are distributed across all zones and regions of the country. Dar es Salaam has the majority of universities relative to other regions of the country..

The University of Dar es Salaam (UDSM) is the oldest university in Tanzania. It was established in 1960 as an affiliate of the University College of London, prior to independence. From 1963 to 1970, it was part of the University of East Africa, together with the University of Nairobi and Makerere University in Kenya and Uganda respectively. According to Mollel (2005), a guiding policy for the higher education in Tanzania was governed by the East Africa member states as a whole, while the university curricula and teaching models were from the University of London.

When established, it had only a faculty of law with only 13 students (UDSM, 2017). Thereafter, more faculties were established, including the faculty of science (1965), the faculty of arts (1967), the faculty of medicine (1968) and the faculty of agriculture (1970). The University of Dar es Salaam became an independent university on the 1st July 1970 under the Parliament Act no. 12 of 1970 (URT, 1970).

Sokoine University of Agriculture (SUA) is the second oldest university in Tanzania and was established in 1984, detached from the University of Dar es Salaam. However, the history of SUA goes back to 1965, when it was an agricultural college (URT, 1984). The history of Muhimbili University of Health and Allied Sciences (MUHAS) goes back to 1963, as the Dar es Salaam Medical School and then became the faculty of medicine of the University of Dar es Salaam (1968). MUHAS became a fully-fledged university in 2005, independent from the University of Dar es Salaam as the Muhimbili University College of Health and Allied Sciences (URT, 2005). The other major universities in Tanzania are the Open University of Tanzania (1992), Mzumbe University (2006), Ardhi University (2007), and the University of Dodoma (2007) which is projected to enrol about 50,000 students by 2025.

Tanzania public service reforms that began in 1995 to 2000 brought about dramatic reform of the government's role in service provision to service promotion and facilitation. The reforms took on board the private sector as a key player in the production of goods and services to boost the Tanzanian economy. This introduced the concept of "Public-Private Partnership" where a number of private universities were established as encouraged by the national higher education policy (URT, 1999:23). For instance, in 1998, there were only three public universities in the country, with an average of 2000 graduates annually (Gaillard, 2003).

Gaillard (2003:322) notes that Tanzania lags behind in the region with the low number of university students, with an estimated 2000 students graduating from universities annually out of a population of 30 million (7 graduates per 100,000). This compares unfavourably with other countries such as South Africa, with 244 graduates per 100,000 population, followed by Namibia (140), Swaziland (64), Kenya (44) and Botswana (40). According to UNESCO (2008), the gross enrolment ratio (GER) for Tanzania in 2004 was about 1%, compared to 3% for Uganda and Kenya, while it is 5% for sub-Saharan Africa as a whole. The low enrolment rate in Tanzania was mainly due to the small size and capacity of the higher education institutions in Tanzania. As URT (2010) also notes, the Tanzanian GER in higher education was still lower (2.2%) than many sub-Saharan countries. The report (URT, 2010) shows that the average GER for sub-Saharan Africa was about 5%, while the GER for individual countries in the region, like Uganda was 3%, Kenya (3%), Rwanda (3%), Ethiopia (3%), Ivory Coast (7%), Nigeria (10%) and South Africa (15%).

From 2004 to 2009, Tanzania implemented the secondary education development programme (SEDP), which intended to increase the enrolment rate of students and improve the quality of secondary education (URT, 2004:2). The programme increased the enrolment rate in both primary and secondary schools, which in turn increased the rate of student enrolments in the higher education programmes. The UNESCO report (2014:98) notes that secondary education enrolment increased seven times from 261,896 students in 2000 to 1,884,272 students in 2012. The report also notes that, during the implementation of SEDP phase I, the number of secondary schools increased three fold from 1,291 schools in 2004 to 4,102 schools in 2009. According to URT (2010), the students' enrolment in the higher education programmes escalated from 37,667 in 2004/05 to 95,525 in 2008/09, which is an increase of 153%. In 2016, the student enrolment in higher education institutions was 224,080 which was a six fold increase since 2004, and the government intends to double the figure to 468,530 by 2020 (Domasa, 2016). The increased enrolments in higher learning institutions will help Tanzania to prepare enough skilled workers in the industrial economy to become a middle-income country by 2025.

3.4.2 Challenges facing higher education institutions in Tanzania

The higher education development programme that started in 2010, aimed at enhancing relevance, access and the quality of higher education, and it played a significant role to increase student enrolments in higher education institutions in Tanzania. The preceding section shows a dramatic increase of the students' enrolment in the higher education system of Tanzania as the result of several initiatives and programmes from the government and private partners. The national higher education policy (URT, 1999:1) acknowledges that challenges face the higher education system, including inadequate teaching and research infrastructures proportionate to enrolled students, staff turnover, inadequate research funding, an imbalance of enrolment between science and art students, etc. The government, private partners and other key players in education need to improve the environment in higher learning institutions, and hence the quality of education.

According to Istoroyekti (2016) and UNESCO (2011), the number and quality of academic staff at the higher learning institutions in Tanzania are inadequate. The UNESCO report (2011) also notes that Tanzanian higher learning institutions have a higher staff/students ratio than is standard, which in turn impairs the supervision and quality of training. In 2016, the government, through MEST, closed one university in the country, and threatened to close more universities after the inspection report revealed that some universities are below standard (Kolumbia, 2016). The quality of higher education must be monitored and evaluated to ensure that students have good skills and knowledge after the completion of their studies. Tables 5.1 to 5.4 show the current list of universities and university colleges accredited by the Tanzania Commission for Universities in Tanzania. Figure 3.4 shows the distribution of the higher learning institutions in Tanzania.

Table 3.1: Tanzanian public universities in 2017

S/N	Name	Main sector	Headquarters
1.	UDSM	Mixed	Dar es Salaam
2.	SUA	Agricultural, Forestry, Veterinary and Biomedical Sciences	Morogoro
3.	Open University of Tanzania (OUT)	Mixed	Dar es Salaam
4	Ardhi University (ARU)	Land and Environment	Dar es Salaam
5.	MUHAS	Medical and Health Sciences	Dar es Salaam
6.	Mzumbe University (MU)	Arts, Humanities and Social Sciences	Morogoro
7.	University of Dodoma (UDOM)	Mixed	Dodoma
8	Moshi Cooperative University	Arts, Humanities and Social Sciences	Kilimanjaro
9.	Nelson Mandela African Institute of Science and Technology (NM-AIST)	Mixed	Arusha
10.	State University of Zanzibar	Mixed	Zanzibar
11.	Mbeya University of Science and Technology (MUST)	Engineering and Technology	Mbeya
12.	Mwalimu Julius K. Nyerere University of Agriculture and Technology	Agriculture	Mara

Data Source: TCU, 2017.

Table 3.2: Tanzanian private universities in 2017

S/N	Name	Main sector	Headquarters
1.	Hubert Kairuki Memorial University (HKMU)	Medical and Health Sciences	Dar es Salaam
2.	International Medical and Technology University (IMTU)	Medical and Health Sciences	Dar es Salaam
3.	Tumaini University Makumira (TUMA)	Arts, Humanities and Social Sciences	Arusha
4.	St. Augustine University of Tanzania (SAUT)	Arts, Humanities and Social Sciences	Mwanza
5.	Zanzibar University (ZU)	Arts, Humanities and Social Sciences	Zanzibar
6.	Mount Meru University (MMU)	Arts, Humanities and Social Sciences	Arusha
7.	University of Arusha (UA)	Arts, Humanities and Social Sciences	Arusha
8.	Teofilo Kisanji University (TEKU)	Arts, Humanities and Social Sciences	Mbeya
9	Muslim University of Morogoro	Arts, Humanities and Social	Morogoro

S/N	Name	Main sector	Headquarters
	(MUM)	Sciences	
10	St. John's University of Tanzania (SJUT)	Mixed	Dodoma
11.	Catholic University of Health and Allied Sciences (CUHAS)	Medical and Health Sciences	Mwanza
12.	Sebastian Kolowa Memorial University (SEKOMU)	Arts, Humanities and Social Sciences	Tanga
13	University of Iringa (UoI)	Arts, Humanities and Social Sciences	Iringa
14	AbdulRahman Al-Sumait Memorial University (SUMAIT)	Arts, Humanities and Social Sciences	Zanzibar
15	Aga Khan University (AKU)	Medical and Health Sciences	Dar es Salaam
16	United African University of Tanzania (UAUT)	Arts, Humanities and Social Sciences	Dar es Salaam
17	Mwenge Catholic University (MWECAU)	Arts, Humanities and Social Sciences	Kilimanjaro
18	Ruaha Catholic University (RUCU)	Arts, Humanities and Social Sciences	Iringa
19	University of Bagamoyo (UoB)	Arts, Humanities and Social Sciences	Coast Region
20	Eckernforde Tanga University (ETU)	Arts, Humanities and Social Sciences	Tanga
21.	St. Joseph University in Tanzania (SJUIT)	Mixed	Dar es Salaam

Data Source: TCU, 2017.

Table 3.3: Public university colleges

S/N	Name	Main sector	Headquarters
1.	Mkwawa University College of Education (MUCE)	Education	Iringa
2.	Dar es Salaam University College of Education (DUCE)	Education	Dar es Salaam

Data Source: TCU, 2017.

Table 3.4: Private university colleges

SN	Name	Main sector	Headquarters
1	Stefano Moshi Memorial University College (SMMUCo)	Arts, Humanities and Social Sciences	Kilimanjaro
2	Kilimanjaro Christian Medical College (KCMUCo)	Medical and Health Sciences	Kilimanjaro
3	St. Joseph University College of Health and Allied Sciences (SJUCHAS)	Medical and Health Sciences	Dar es Salaam
4	St. Francis University College of Health and Allied Sciences (SFUCHAS)	Medical and Health Sciences	Kilombero
5	Tumaini University Makumira, Dar es Salaam, Dar es Salaam College (TUMADARCo)	Arts, Humanities and Social Sciences	Dar es Salaam
6	Arch Bishop James University College (AJUCo)	Arts, Humanities and Social Sciences	Ruvuma
7	Archbishop Mihayo University College of Tabora (AMUCTA)	Arts, Humanities and Social Sciences	Tabora
8	Stella Maris Mtwara University College (STeMMUCO)	Arts, Humanities and Social Sciences	Mtwara
9	Jordan University College (JUCo)	Arts, Humanities and Social Sciences	Morogoro
10	Kampala International University (Dar es Salaam Constituent) College (KIU-DAR)	Mixed	Dar es Salaam
11	St. Joseph University College of Management and Commerce (SJUCMC)	Arts, Humanities and Social Sciences	Njombe
12	Cardinal Rugambwa Memorial University College (CARUMUCo)	Arts, Humanities and Social Sciences	Kagera
13	Josiah Kibira University College (JOKUCo)	Arts, Humanities and Social Sciences	Kagera
14	Marian University College (MARUCo)	Arts, Humanities and Social Sciences	Coastal Region

Data Source: TCU, 2017.

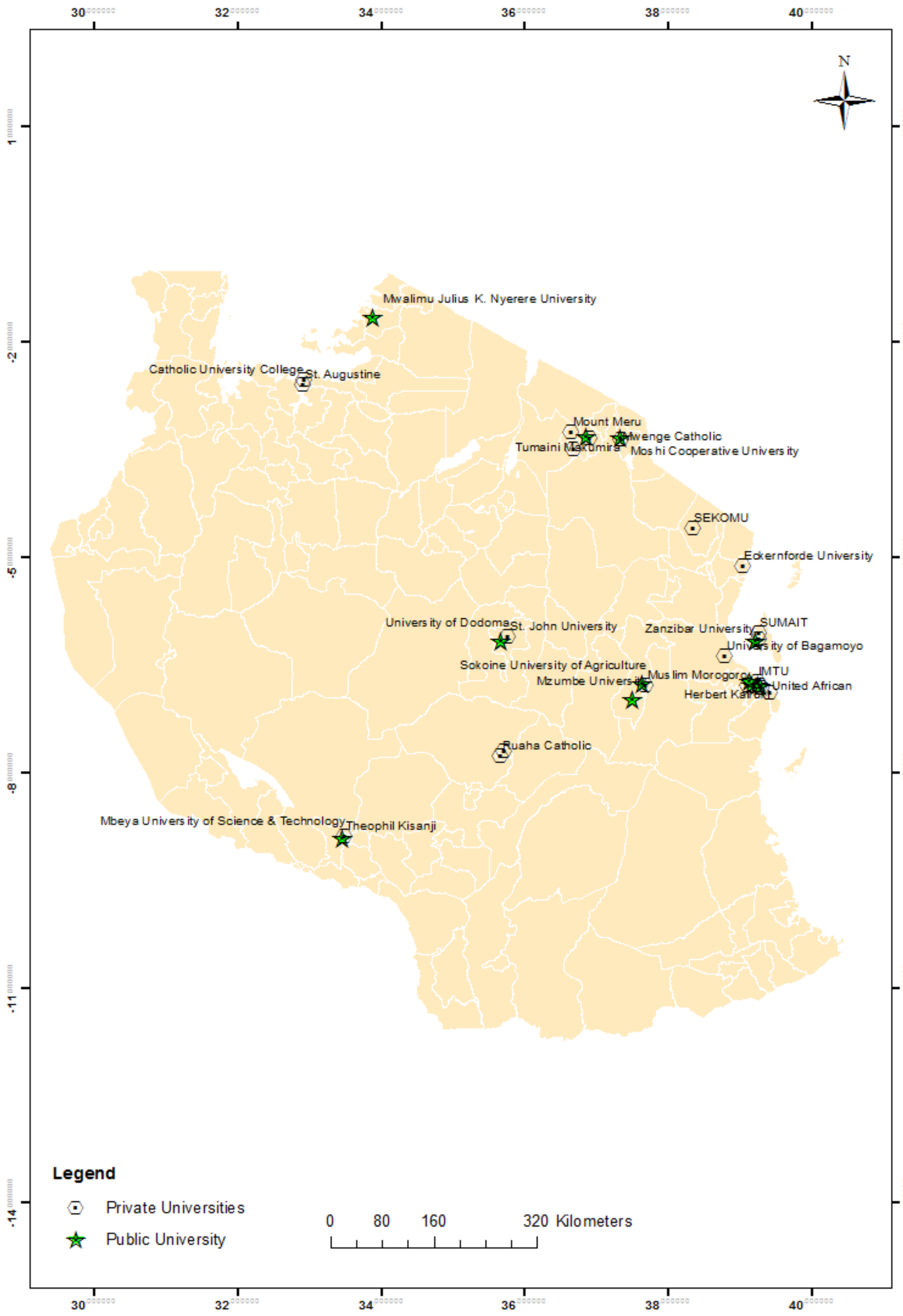

Figure 3.4: Distribution of higher learning institutions in Tanzania in 2017

3.4.3 Public research institutions

There are 25 public and private research institutions in Tanzania (COSTECH, 2017). The research institutions fall under different sectoral ministries and are affiliated to COSTECH, as the research coordinating body in the country. Most of the research institutions are government based with a few being privately owned research institutions. The public research institutions receive their operational budget (salaries, operational cost and some amount of development funds) from the parent ministries through the parliamentary grants. The agriculture, livestock, and medical research institutions are well established and strategically located in all zones of the country and most of them came into existence during the colonial era.

There are twenty public research institutions in Tanzania. The public research institutions report to the different parent sectoral ministries for operational purposes. COSTECH is in overall charge for the coordination of all research and innovation activities, which are performed by R&D institutions in the country. The agriculture, livestock, and health research institutions have several centres, which are strategically distributed, over the different zones of the country. TARI has 13 agricultural research centres, Tanzania Veterinary Laboratory Agency (TVLA) has 11 veterinary research centres, TALIRI has 7 livestock research centres, and NIMR has 7 medical research centres (COSTECH, 2017). This shows that there are 18 public livestock and veterinary research centres altogether and 16 public agriculture-related research centres in the country, as Table 3.5 below displays. Most of the agriculture, livestock and health research institutions were established during the colonial administration. Therefore, the colonial legacy to the aforementioned research institutions is fundamental for the existence and performance of the institutions. TAWIRI, TAFORI and TAFIRI also have several research centres in the country, as Figure 3.5 below illustrates.

Apart from these research institutions mentioned above, there are also several other sectoral research institutions, which perform R&D activities in Tanzania, such as the Tanzania Industrial Research Development Institute, the Tanzania Engineering and Manufacturing Design Organization, the Tanzania Automotive Technology Centre, the Tropical Pesticides and Research Institute, the National Housing and Building Research Agency, etc.

3.4.4 Private research institutes

The Ifakara Health Institute (IHI) is one of the few private research institutes established in 1956 as the Swiss Tropical Institute Field Laboratory under the Swiss Tropical Institute, Basel, Switzerland (IHI, 2017). Over the past decade, IHI is one of the top five prolific R&D institutions in terms of publication outputs in the country, as will be shown in Chapter 6. The other private research institutions are the Tanzania Coffee Research Institute (TACRI), the Tea Research Institute of Tanzania (TRIT), Tanzania Technology Development Organization (TaTEDO), Research for Poverty Alleviation (REPOA) and the Economic and Social Research Foundation (ESRF).

3.4.5. International research institutions

There are three international research institutions, which perform research in Tanzania. These research institutions fall under the agriculture and livestock sectors and they are located in Dar es Salaam. These research institutions include the International Livestock Research Institute (ILRI), the International Rice Research Institute (IRRI) and the International Institute of Tropical Agriculture (IITA) which are all located in Dar es Salaam. Table 3.5 and Figure 3.5 show a list and the distribution of research institutions in Tanzania.

The total of public, private and international research institutes or centres that are related to agriculture and livestock sectors in the country are about 37. The huge number of research institutions or centres related to agriculture could be explained by the fact that these sectors were and are important in the country before and after independence. Additionally, agriculture is the backbone of the country and the majority of the population (70%) depends on this sector for their livelihoods.

Table 3.5: Research institutions in Tanzania in 2017

Sector	Research institutions	Ownership	Headquarters
	TARI TARI centres: • Makutupora centre • Mikocheni centre • Ilonga Centre • Ukiriguru centre • Selian centre • Maruku centre • Naliendele centre • Ifakara centre • Kibaha centre • Dakawa centre • Homboro centre • Tengeru centre • Mlingano centre	Public	Dodoma
	TPRI	Public	Arusha
	Tobacco Research Institute of Tanzania (TORITA),	Public	Tabora
Agriculture	Kizimbani Agriculture Research Institute	Public	Zanzibar
	TACRI	Private	Kilimanjaro
	TRIT	Private	Iringa
	IITA	International	Dar es Salaam
	International Rice Research Institute	International	Dar es Salaam
Livestock and Fisheries	TAFIRI TAFIRI Centres: • Dar es Salaam centre • Kyela centre	Public	Dar es Salaam

Sector	Research institutions	Ownership	Headquarters
	• Mwanza centre • Kigoma centre • Sota (substation)		
	TALIRI TALIRI Centres: • TALIRI Mpwapwa • TALIRI Uyole • TALIRI Mabuki • TALIRI Naliendele • TALIRI West Kilimanjaro • TALIRI Tanga • TALIRI Kongwa	Public	Dodoma
	TVLA TVLA Centres: • Central Veterinary Laboratory • Centre for Infectious Disease and Biotechnology • Vector & Vector-Borne Diseases Research Institute (VVBDI) Tanga • TVLA Tabora • TVLA Dodoma • TVLA Mwanza • TVLA Arusha • TVLA Mtwara • TVLA Iringa • Tanzania Vaccine Institute • VVBDRC Kigoma	Public	Dar es Salaam
	ILRI	International	Dar es Salaam
Natural Resources	TAFORI TAFORI Centres: • Dodoma Arid Zone Afforestation Research Centre • Kibaha Lowland Afforestation Research Centre (LARC) • Silviculture Research Centre • Malya Lake Zone Afforestation Research Centre • Moshi Timber Utilisation Research Centre • Mufindi Pulpwood Research Centre • Miombo Woodland Research Centre	Public	Morogoro
	TAWIRI TAWIRI Centres: • Serengeti • Mahale/Gombe • Njiro • Kingupira	Public	Arusha
Medical and Nutrition	NIMR NIMR Centres:	Public	Dar es Salaam

Sector	Research institutions	Ownership	Headquarters
	• Amani Research Centre • Mwanza Research Centre • Muhimbili Research Centre • Tabora Research Centre • Tanga Research Centre • Mbeya Research Centre • Tukuyu Research Centre • Ngongongare		
	Tanzania Food and Nutrition Centre (TFNC)	Public	Dar es Salaam
	IHI IHI Centres • IHI Ifakara branch • IHI Bagamoyo branch	Private	Dar es Salaam
	Kilimanjaro Clinical Research Institute (KCRI)	Private	
Social Economic	REPOA	Private	Dar es Salaam
	ESRF	Private	Dar es Salaam
Energy and Industry	TIRDO	Public	Dar es Salaam
	TEMDO	Public	Arusha
	National Housing and Building Research Agency (NHBRA)	Public	Dar es Salaam
	CAMARTEC	Public	Arusha
	TATC	Public	Coast Region
	SIDO	Public	Dar es Salaam
	Tanzania Atomic Energy Commission (TAEC)	Public	Arusha

Data source: COSTECH, 2017; URT, 2016

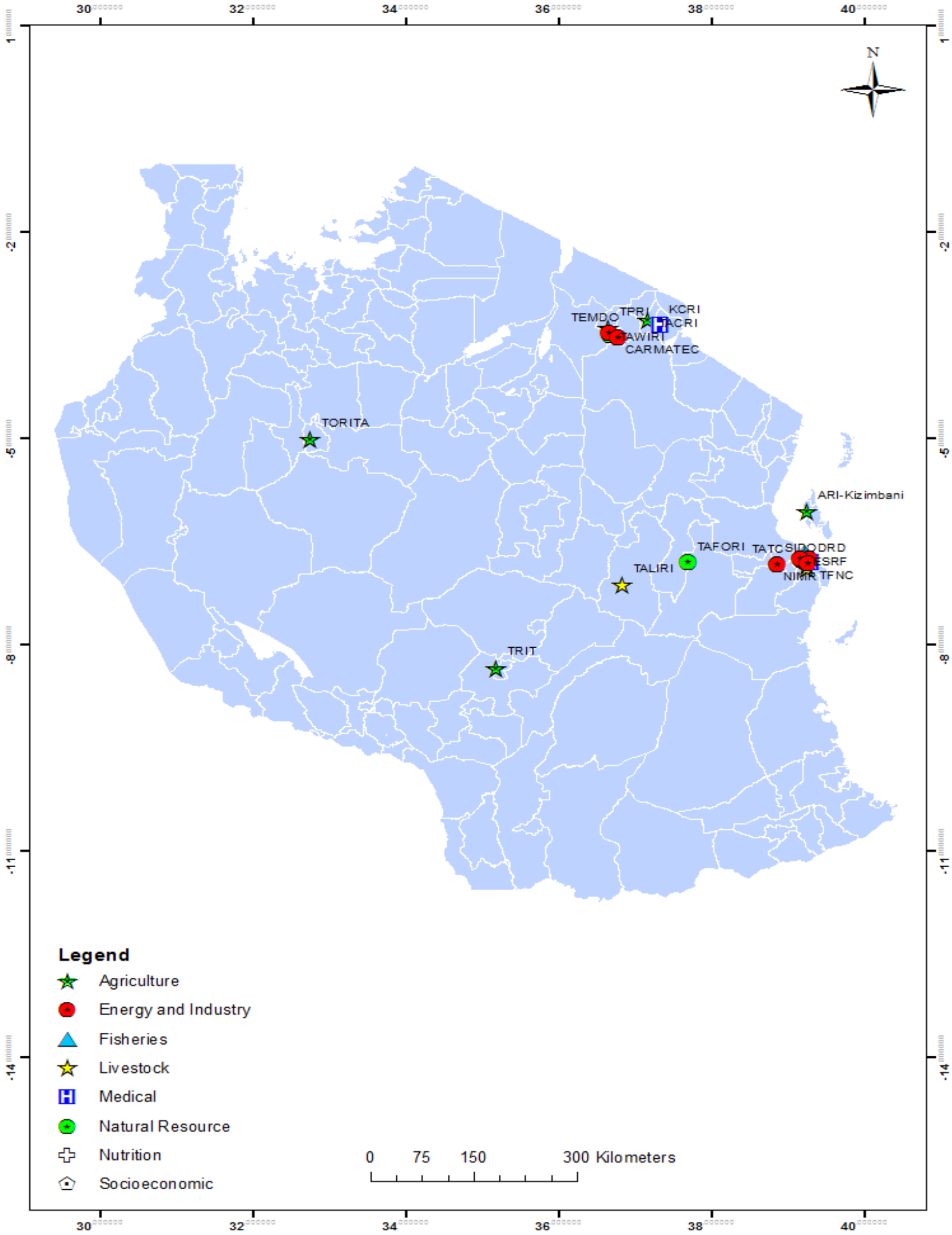

Figure 3.5: Distribution of research institutions in Tanzania in 2017

Over the years, R&D institutions in Tanzania conducted many research activities and came up with tangible outputs for the benefit of the country. There are a number of salient achievements of the Tanzanian science and technology policy. As the National Research and Development policy notes (URT, 2010), the following are the achievements of R&D activities in the country:

i. Eradication of tsetse flies in Zanzibar;

ii. The evaluation of health interventions against major disease burdens through the use of drugs and treated nets;

iii. The production of *Boswellia* species and the commercialisation of Frankincense in the dry lands of Eastern Africa;
iv. The conservation of indigenous fruits and the development of tree biotechnology;
v. The development of new drugs and formulations from indigenous plants for treating skin diseases and creating nutritional supplements, immune-boosters and anti-malarial drugs;
vi. The breeding of crop varieties that have been fully commercialised;
vii. The development of improved breeds of cattle, goats, sheep, and chickens;
viii. The evaluation of pesticides against various pests and diseases;
ix. The introduction and commercialisation of seaweed farming;
x. The development and dissemination of equipment and machinery for agro-processing, mining, construction, animal traction, transportation, etc.;
xi. The development of better environmental and natural resources management methods.

3.5 Conclusion

Science and technology policy is a vital roadmap to guide the implementation of R&D programmes to tap the potential of science and technology. Science and technology policy guides R&D stakeholders to the effective and efficient utilisation of resources in finding solutions for societal needs. The implementation of science and technology policy depends on the proper allocation of funds to R&D programmes and activities. From the findings above, R&D investment in Tanzania needs to be increased to reach 1% of the GDP as stipulated in the R&D policy. Most of the R&D institutions in the country are underperforming mainly due to insufficient research funding and dilapidated research infrastructure. The country has to increase the budget for research activities and devise alternative sources to ensure reliable and sustainable R&D investment. The third version of the science and technology policy over the three decades will have no significant impact if the trend of R&D investment remains the same. The low level of commercialisation of research outputs is not a good indicator for the Tanzanian innovation system and for the country looking to become a middle-income country by 2025.

Awareness of the creation and sensitisation of the commercialisation of research outputs is essential for researchers, R&D institutions, as well as for job and wealth creation. There is a need to sensitise researchers regarding IPR to protect their innovations, and hence benefit from research outputs. The low quality of industrial products in Tanzania remains a challenge, which needs to be resolved to be competitive in this era of free-market economies and trade liberalisation. Additionally, the government has to promote local innovation firms and industries through incentive schemes e.g. tax relief, grants and the availability of supporting financial institutions.

The size of the Tanzanian workforce in the R&D system is still small in comparison with many countries in the region. Strengthening the capacity and capability of R&D institutions by increasing the number of researchers is fundamental in ensuring a competitive industrial economy in the country. The human resource capacity building in terms of postgraduate training and technical skills should be increased to tap the potential of science and technology in Tanzania. The county needs a stronger and reflective R&D workforce, and an STI system that is more responsive to current and future societal needs.

The NSI in Tanzania has been characterised by fragmentation and a sluggish rate of technology transfer from R&D institutions to the industrial sector. Restructuring the legal and institutional frameworks is therefore very necessary to ensure well-organised technology transfer, as well as stronger linkages between the government, R&D institutions, industry, and the business sector. Additionally, the formulation of institutional frameworks for the efficient coordination of R&D institutions is essential. The frameworks should provide COSTECH with a clear mandate and power over all affiliated R&D institutions, hence a smooth coordination role. The STI policy should be holistic, taking into account all sectoral policies streamlined with the STI policy for inclusive development. In addition to that, there is a weak interaction between industry and academia, which brings about the failure of the commercialisation of research outputs. There is also insufficient financial support for start-up capital for new firms and spin-off companies.

CHAPTER 4: ANALYTICAL FRAMEWORK AND RESEARCH METHODOLOGY

4.1 An analytical framework for the review of the STI system

The analytical framework employed in the assessment of the Tanzania research performance was adopted from the framework developed by Mouton (2015) for South Africa, which is specific for assessing research performance as shown in figure 4.1 below. The Research and Innovation Performance Framework (RIPF) by Mouton is based on four research and innovation (RI) performance dimensions: Research and innovation investment; Research and innovation capacity; Research and innovation outputs and Research and innovation impact. The four RI dimensions have been disaggregated to several related indicator categories for easily monitoring and assessing the research performance. The conceptual framework applied in this thesis in the assessment of the Tanzania research performance could be the basis and harmonized in the R&D institutions in the country.

Sugimoto and Larivière (2018:1) group the measuring of research activity into **input, outputs, and impact** dimensions. The authors explain that the common inputs indicators included the size and characteristics of the scientific workforce and research funding. The impact indicators measure the way scholarly literature has an impact on research and general society. Science indicators are built from a wide range of data sources by means of national and international R&D surveys and the data have the endorsement of major government and international scientific organizations the UNESCO and OECD (Sugimoto & Larivière.2018:2). The advantage of these data sources offers de facto standards for reporting which are easily grouped, more inclusive than local surveys and relatively stable over time.

RI DIMENSIONS	RI PERFORMANCE CATEGORIES	INDICATOR CATEGORIES
RI Impact	Scientific impact	Citation impact
RI Outputs	Research publications	Papers in Web of Science Papers in Local accredited journals
	Graduate outputs	Masters graduate Doctoral graduate
	Innovation outputs	Patents
RI Capacity	Human resources for S&T	Researchers R&D personnel Academic staff
	Level of collaboration	International collaboration
RI Investment	Public investment	Public expenditure on RI
	Private investment	Business expenditure on RI

Figure 4.1: Conceptual Framework for Research and Innovation Evaluation

Source: Mouton, 2015.

This study sought to map Tanzania science by applying bibliometric data from the Web of Science database for the period of 14 years from 2005 to 2018. The bibliometric study among other things also analysed the production of scientific knowledge, visibility of produced scientific outputs, and the strength of produced knowledge across scientific fields relative to the World, collaboration patterns and so forth. All results were disaggregated scientific field into the natural science, health sciences, agricultural sciences, social sciences, humanities, engineering, and applied technologies.

4.2 Research design and methodology

This study is defined a case study where the case is the 'Tanzanian science system". A case study focuses intensively on a single case. A case study is defined as:

> *[A]n intensive study of a single unit for the purpose of understanding a larger class of (similar) units*. A unit connotes a spatially bounded phenomenon, e.g. a nation-state, revolution, system, political party, election, or person observed at a single point in time or over some delimited period Gerring (2004:342).

A case study is typically more useful in descriptive and exploratory studies but can also generate explanatory statements of the case under investigation (Mouton, 2000; Gerring, 2004:346). Case study facilitates the construction of detailed and provides more insight into the phenomenon under investigation (Mouton, 2000; Hodkinson & Hodkinson, 2001). As noted by Yin (2012) a case study research is applied as an exploratory instrument preceding the application of other methods, such as surveys and experiments. Yin (2012) also stressed that apart from an exploratory study, a case study research can also be used in descriptive, explanatory, and evaluative approaches. The qualitative case study research method provides tools for scientists to study complex phenomena within their contexts (Baxter & Jack, 2008).

Again, according to (Yin, 2012), it is suitable to apply a case study research design when: (a) the focus of the research is to answer "how" and "why" questions; (b) you cannot control the behaviour of respondents in the research study; (c) you want to cover contextual situations because you believe they are relevant to the phenomenon under study. Yin (2012) further noted, when a case study research method is applied poorly, the study could lead to unreliable research results.

Conventionally, the application of case study design has been related to qualitative methods of analysis. Gerring (2007:10) argue that this offhand application has to be understood as a methodological affinity, not a definitional entailment. Gerring further stresses that in a case study research design, a researcher needs not to limit himself to qualitative methods. It can be either quantitative or qualitative and sometimes a combination of both approaches can be applied. We elaborate on these methodological issues below.

This study combines quantitative and qualitative methods. As noted by Neuman (2011:163) and Kelle (2006:294) combining qualitative and qualitative methods in a single study build on the complementary strengths of both methods. Additionally, Hammond (2005:241) urged that mixing research methods is valuable simply because each method offers a different perspective on the topic under investigation. Hammond also stressed that (2005:241) in the mixed research approaches, data collection, questions investigation and the way evidence is analysed and interpreted complement each other.

A mixed methods design involves the collection and analysis of both quantitative and qualitative approaches in many phases of the research process in a single study (Tashakkori &Teddlie, 2003; Creswell & Plano Clark, 2007:5). It focuses on collecting, analysing and mixing both quantitative and qualitative data within in a single research study. Its central premise is that the uses of quantitative and qualitative approaches, in combination, provide a better understanding of research problems than either approach alone (Creswell & Plano Clark, 2007:5). The justification for mixing research method designs within one study is grounded in the fact that neither quantitative nor qualitative approach are enough to capture the phenomenon under investigation Ivankova, Creswell & Stick, 2006:3)

A mixed research methods approach offers essential tools to overcome limitations of both quantitative and qualitative methods when are applied separately and provides a more robust analysis by taking advantage of the strengths of each approach (Greene et al., 1989; Miles & Huberman 1994; Tashakkori &Teddlie 1998). It provides opportunities for the exploration of the quantitative findings in more depth. The following are the advantages of applying mixed research methods as noted by Kelle (2006:309).

a) In a sequential quantitative-qualitative approach, quantitative research can help to guide the selection of cases in qualitative small n studies.
b) Results from qualitative interviews can help to identify unobserved heterogeneity in quantitative data as well as previously unknown explaining variables.
c) Results from the qualitative part of mixed-methods approach can help to understand previously incomprehensible statistical results.
d) A quantitative study can help to corroborate findings from a qualitative study and to transfer these results to other domains.

Additionally, several scholars including Greene et al., (1989) in their review argued the potential benefits of application of mixed research approach. In their study, (Green et al., 1989) list five advantages of using mixed research methods which are: (a) triangulation – try to find out the convergence or validity of findings; (b) complementarity - elaboration, enhancement, illustration and clarification of findings; (c) initiation - discovering fresh perspectives through paradoxes and obvious contradictions; (d) development - seeks to use the findings from the first methods to inform the other method; and (e) expansion - seeks to extend the breadth or scope of the study.

The study by Creswell et al. (2003) and Kelle (2006:308) also note that it is very useful to combine qualitative and quantitative methods by starting with a quantitative study, followed by a qualitative inquiry. In this design, quantitative data were collected and analysed first then the qualitative data are collected and analyzed second to provides explanations for some of the quantitative findings obtained in the first stage (Creswell et al. 2003). In such sequential quantitative research is done to identify problem areas and research questions that need deeper insight through the application of the qualitative approach. In other words, the qualitative method and data analysis refine and provides explanations for quantitative findings by exploring respondents' views in more depth (Tashakkori & Teddlie 1998; Creswell 2003).

Following this mixed method approach, this study involves three methodological components. The first is the historical study (discussed in Chapter 2) and which provides some context on the history of research in Tanzania before and after independence. The second refers to scientometric analyses of R&D investmentand the human resources capacity of the system and bibliometric analyses of scientific publications, trends, and distribution across the scientific fields, top performing R&D institutions, impact of publication outputs, relative field strengths, collaboration patterns and positional analysis across scientific domains. The third refers to the (secondary analysis of survey data from Tanzania researchers as well as a small number of qualitative interviews.

4.2.1 Historical study

This part of the study involved an overview of the genesis and development of research institutions in Tanzania pre and post-independence (Chapter 2). It is important to understand the history of science in Tanzania to provide a necessary context for the scientometric, survey and qualitative data analysis of this study. Therefore, the first part of the historical study collected and analyzed the relevant archives regarding the establishment and organization of the R&D institutions in the country during the colonial era. The second part of the historical research involved collection of information on the governance, policy and institutional landscape of Tanzanian science and technology after independence in 1961 (Chapter 3). These two chapters provides information on the history of Tanzanian sciences as well as more recent developments about the key component of the science system. In the remainder of the study we proceeded to analyse the performance of the science system keeping the historical and contextual information in mind.

4.2.2 Scientometric and bibliometric analysis

Scientometric analyses in this study referred to those indicators of national scientific performance that are typically derived from R&D survey. These indicators would include both indicators of R&D expenditure (GERD/GDP, sources of R&D funding and so on) as well as indicators related to the human resource base of the country (number of headcounts and full-time equivalent researchers and research workers in the country disaggregated by sector and research field.

Bibliometric analyses – which is a subset of scientometric – specifically focusses on the analysis of scientific documents and texts. Such bibliometric analyses are commonly derived from electronic citation databases, comprising bibliographical information of scientific publications and citations. Among these literature databases, the Web of Science (WoS) and Scopus databases are regarded as the most comprehensive and reliable and most commonly used for bibliometric analyses. The data analysis presented in the bibliometric section is based on the scientific publications (articles and reviews) over a decade covered in the Web of Science database for the period 2005-2018. Despite limitations in coverage (e.g. by discipline, language and country), citation databases have become the standard tools for assessment of research using scientometrics method (Sugimoto & Larivière, 2018:2). Bibliometrics analyses was employed to evaluate the performance of the Tanzania R&D institutions in terms of publication outputs, publication trends, top performing R&D institutions in the country, citation impacts trends, distribution across the scientific fields, positional analysis across scientific fields, and other related indicators.

The following are the main bibliometric indicators included in this study:

Number of publications: As a simple indicator of the overall publication outputs, it provides a count of scientific publications within and across scientific fields. It can be used in measuring and comparing the research performance at institutions, regions or national levels.

Specialization index (SI) synonymous with Relative Field Strength (RFS). The indicator shows the concentration of literature produced in a particular field, taking the world proportion as the standard. It reflects the research intensity or effort of an entity, in a particular scientific field, relative to the world average in the same research field. The RFS above 1 means that entity scores higher (or specialized) in that scientific field or subfield above the world average, whereas index value below 1 indicates that an entity in that scientific domain scores below the world average.

Mean Normalized Citation Score (MNCS): It is a commonly known fact that subject-specific peculiarities of publication and citation behaviour differ hugely between scientific disciplines, it is not possible to compare the raw numbers of citations received by papers in different disciplines Glänzel et al., 2009. This is due to differences among scientific fields in the average number of cited papers per publication, the average number of years of cited papers, and the degree to which references from other fields are cited (Waltman et al., 2011:37; Glänzel et al., 2009). Therefore, it is essential that careful control is in place for the differences of the scientific fields especially in the case of performance evaluations at higher levels of aggregation, such as at the countries or multidisciplinary research groups (Waltman et al., 2011:37). According to Van Raan (2005), in performance evaluation research, the Centre for Science and Technology Studies (CWTS) of Leiden University, the Netherlands uses a standard set of bibliometric indicators that relies on a normalization of scientific fields that aims to correct for the differences among fields. According to the author, this kind of normalization of indicators is also done by the Centre for R&D Monitoring (ECOOM) in Leuven, Belgium. Therefore, a common indicator that corrects this issue is the MNCS, which is normalized for both the scientific disciplines associated with a publication as well as the year of publication. For instance, an MNCS of 2, means that the papers of the country (in this scenario) have been cited twice above the world average of the fields in which they published in a specified year or citation window. According to the convention established by the Centre for Science and Technology Studies (CWTS) at the University of Leiden, an MNCS of 1 indicates that a country's citation impact is corresponding with the world average in the selected fields. A MNCS between 0.8 and 1.0 is regarded as reasonably good, while an MNCS between

1.0 and 1.2 is considered good. Anything above the value of 1.2 is regarded as very good (Mouton, 2019).

Positional analysis: The analysis provides the interpretation of relative field strength and weaknesses of a given scientific domain by combining three indicators in a two-dimensional space with four quadrants. The horizontal axis corresponds to the SI while the vertical axis reflects the impact of a given scientific field or subfield.

Collaboration profile: In recent years, there has been an increasing emphasis by research funders and R&D institutions on the importance of research cooperation. Some research works are viable with the participation of several researchers coming from different institutions and countries. Therefore, there is a great need for reliable scientific measurement of the collaboration trends. The bibliographic data provides great opportunities to analyse the research collaboration trends of a given country by measuring the number of joint publications. In this study, research cooperation has been grouped into four categories namely: No collaboration (single-authored publications), national collaboration rate, Africa collaboration rate, and international collaboration rate.

Research funding: The bibliometric analysis of the study also analysed data from the Web of Science on "funding acknowledgement" of Tanzania authored publications for the period of fourteen years (2005-2018) to identify the main research funders in the. The findings have been triangulated with the secondary survey results on research funding to find out the convergence of findings from both data sources.

Limitations of bibliometrics

It is important to recognize that bibliometric methods have some limitations in the measurement of research performance. As noted by King (1987) below are the limitations of bibliometric to its use for performance assessment in scientific research.

1. Citation analysis assumes that referenced scientific articles revealed facts that were essential to the work shown in the citing article.
2. The incorrect study may be highly cited and increase the research impact.
3. Self-citation may results to artificially increase of scientific impact of researchers and hence portray the untrue situation. The citation indicator used in this study excluded self-citations counts.
4. The counting of the number of citations by the WoS could results in an error (e.g., institution, country) due to indexing errors arising from different ways of citing the name of an author and/or institution.

5. Researchers in different scientific fields do differ in citation behaviour. For instance, biomedical scientists cite more than mathematicians. Hence, the publications and citations of these scientific fields should not be directly compared before field normalization.
6. The WoS coverage of literature has a bias in favour of countries that publish in the English language. Thus, countries tend to publish more in other languages, their scientific literature is under covered. It is an advantage for the Scopus database since it covers both English and non-English literature.

4.2.3 Secondary analysis of survey and qualitative data

The study included a secondary analysis of survey data which was collected as part of the Young Scientists in Africa (YSA) project which was hosted at the Centre for Research on Science and Technology (CREST) in collaboration with the Polytechnique Montreal Canada. The secondary survey data was collected by the YSA research team between May 2016 and February 2017. The YSA project collected survey and qualitative data from 22 African countries including Tanzania. Researchers (respondents) from Tanzania where identified through corresponding authors' emails from the Web of Science (WoS) and Scopus databases with bibliometric data from 2005 to 2016. 1738 structured self-administered questionnaires were distributed through CheckBox[1] platform. When the survey exercise was closed, 142 completed questionnaires mainly from Tanzanians had been received.

After the data collection of the Young Scientist in Africa project, data cleaning, (re)coding were done. All the responses to the open-ended questions and "other" responses were cleaned by standardising and creating new variables. The Statistical Package for the Social Sciences (SPSS) software was used to create new variables for analysis. The secondary analysis of the survey data investigated research publication outputs, publication trends across the scientific fields, and the impact of publications of scientists. The analysis of the survey data also analysed the research-funding landscape and factors influencing the research performance of scientists and career development. The study analysed the research-funding mechanisms, collaboration patterns, choice of employment and related factors that influence the performance of research.

The survey questionnaire which was used by the YSA project took into account relevant factors that could influence the research performance of scientists in the country. The dimensions included educational background, employment category, research output, research funding, challenges, international mobility, collaboration, mentoring, demographic background and working conditions as

[1] https://www.checkbox.com/

appendix 4.2 displays. Considering the African context and the research questions, the questionnaire of this study was adapted from the Global State of Young Scientists precursor study (GLOSYS) by Friesenhahn and Beaudry (2014) and for GLOSYS in ASEAN by Geffers et al., (2017). The survey questionnaire is attached as Appendix 4.1.

The study also analysed the interview transcripts which was produced by the YSA project team. The secondary qualitative analysis of this research involved in-depth semi-structured interviews with selected survey respondents (84 respondents) who agreed during the survey exercise to be contacted for the interview. Out of 84 respondents, 10 scientists were interviewed by the YSA project team to provide more information on the performance of research. The in-depth interviews intended to provide a deeper understanding into the factors that influence the research performance of researchers in Tanzania. Respondents were requested to give explanations on several issues in the survey which include research funding, research collaboration, international mobility, mentoring and training and the main challenges that impact on their research performance. The interviews were conducted through skype and telephone. The sampling frame of the researchers who were interviewed are the 'outliers' in the survey analysis, for instance, those scientists who succeeded to produce the high quantity research outputs despite limited support in terms of research funding. The in-depth interviews of the study aimed to triangulate the findings of the bibliometric analysis, the secondary survey analysis and previous studies on the main issues that influence the research performance and career development of researchers in Tanzania. All interviews were recorded, transcribed, and analysed by using the qualitative data analysis software (Atlas/ti). We conclude our discussion of the methodologies used in the study by summarizing how each of the analyses map to the main research questions of the study (Table 4.1) below:

Table 4.1: Analytical framework outlining the main themes and sub-themes for the presentation and results of Scientometric indicators, R&D survey and analysis of survey data.

Main themes	Sub-themes	Research questions	Methods
Research and innovation investment	National and international research funding.	• Who are the top research funders in Tanzania? • What are the main trends in government funding from 1995 to 2013?	Scientometric and bibliometric indicators
	Trends in terms of investment by scientific fields.	• What are the main trends in terms of investment by scientific field?	
Scientists' working environment	Main factors influencing performance of scientists.	• What are the main factors that influence the research performance of scientists in Tanzania? • How are these factors related to access to resources, networks and	Survey and interviews

Main themes	Sub-themes	Research questions	Methods
		collaborations, mentoring and intentional support for the young scientists in Tanzania?	
Research and innovation capacity	Human resources base of Tanzania R&D institutions	• What are the features and size of the human resources base of Tanzania R&D institutions • What are the main factors influencing the performance of scientists	Scientometric indicators and R&D survey
Research performance: Publications and citation impact	Trends and distribution across the scientific fields	• What are the main trends of scientific publications between 2005 and 2018? • What is the sector-wide distribution of publication outputs?	Bibliometrics
	Top performing R&D institutions	• Which are the top R&D institutions in terms of publication outputs?	
	Impact, relative field strengths and positional analysis across scientific fields	• What is the Tanzanian relative field strength of scientific domain outputs globally? • What are the trends in the citation impact of Tanzanian science between 2005 and 2018? • Which are the high impact fields? • What is the Tanzanian positional analysis for produced scientific domains globally?	
Research performance: Research collaboration	Research collaboration profile and intensity	• What are the research collaboration rates in Tanzania (national, regional and international)? • How do research collaboration patterns differ between different scientific fields? • Is there an association between receiving research funding and collaboration?	Bibliometrics Survey data
	Gender difference, research funding and collaboration	• Are there gender differences in research collaboration?	

CHAPTER 5: EXPENDITURE ON R&D, SOURCES OF FUNDING AND ITS IMPACT OF SCIENTIFIC CAREERS

5.1 Introduction

The allocation and disbursement of research funds in most of the SADC countries, including Tanzania, is still facing challenges due to several reasons, including the lack of government commitment to support research (Mouton, Boshoff, Waal, Esau, Imbayarwo, Ritter & van Niekerk., 2008). The study also shows that most of the R&D institutions in the SADC region, excluding South Africa, depend heavily on foreign support to fund their research. These findings are in line with the much earlier study by Gaillard and Waast (1999) which similarly showed that Tanzania depends on foreign support in research capacity building, including MSc and PhD studies. These authors indicated that the Tanzanian science system is surviving because it attracts external research funding. Without external financial support, numerous research projects in Tanzanian universities and research institutions could support very little research projects. Furthermore the previous reports show that The University of Dar es Salaam (UDSM) and the Sokoine University of Agriculture (SUA) during 1980's and 1990's were heavily depending on foreign support for research funding (Gaillard & Zink, & Furo-Tullberg. 2002:21). The authors indicated that the main research funders were Norway, Denmark, Sweden, the Netherlands, Germany and Finland. According to COSTECH (2005b:19) the R&D survey report for the period of 10 years (1994-2004) indicated the proportion of research funding from external sources was 51%, 31% own generated sources, 14% was from the government, and 4% from domestic sources. According to United Nations (2016) many countries have committed to increase R&D investment to meet the Sustainable Development Goals (SDGs). The UNESCO science report also indicated an increase of the world Gross expenditure on R&D (GERD) from a total of Purchasing Power Parity of $1. 1 billion in 2007 to a Purchasing Power Parity of $1, 478 in 2015 (UNESCO, 2015). The R&D funding magazine (2018) indicated that the global R&D spending would be about $2.2 billion in 2018 for the 116 countries that have high investment intensity in R&D. Global R&D spending by 2018 was also dominated by developed countries: the USA (25.25%), China (21.68%), Japan (8.52), Germany (5.32%), South Korea India (3.80), (4.03%), Turkey (3.3%), Israel (3.0%), Canada (2.34%) and France (2.25%). With the exception of South Africa and Egypt, African countries have contributed the least share of total global R&D spending compared to the amounts invested by the USA, Europe and Asia (R&D Magazine, 2018). Despite the minimal share of global R&D investment by Africa, African countries committed to increasing the spending on R&D at least to 1% of GDP (NPCA, 2010; 2014). R&D spending is crucial for the production of knowledge, products and services for the social development of countries. Developed countries depend on highly skilled workers as well as new knowledge for the social economic development (Asongu & Nwachukwu, 2017; Chen & Dahlman, 2005). The significance of new knowledge, improved products and services in economic growth has brought about an increase in research and innovation spending. However, several reports and statistics have indicated that R&D investment in many African countries is less than 1% of their GDP (NPCA, 2010; 2014).

R&D spending in Tanzania is inadequate and lags behind several other African countries. According to COSTECH (2005b) and UIS (2018), there has been a slight increase in Tanzanian R&D expenditure over the period of 2004–2013, from 0.2% GERD of GDP to 0.5% in 2013. Under the NEPAD agreement, all member states, including Tanzania, agreed and signed to increase R&D spending to 1% of GDP by 2008. However, Tanzania is still behind the agreed target. The report on the Tanzanian R&D survey that was conducted in 2005 indicates that some R&D institutions did not receive research funds for several years (COSTECH, 2005b). That means the institutions were inactive or conducted research projects financed by foreign organisations. The analysis of the funding acknowledgment on the Tanzanian bibliometric data extracted from the WoS for eleven years (2005-2016) also showed heavy research donor dependence (WoS, 2018).

The UNESCO science report also indicated that most research activities in Tanzania are largely donor-supported with donor funds ranging from 52% to 70 % of the total GERD (UNESCO, 2015:560). The most current available data from the World Bank show that in 2013 the national expenditure on R&D was 0.53% of the GDP (World Bank, 2019). The availability of updated R&D spending data and other R&D indicators is one of the challenges facing many developing countries, including Tanzania. As shown above, the most recent R&D spending indicators in Tanzania were for the year 2013.

5.2 Main trends in public expenditure on R&D

The trend in the R&D expenditure in Tanzania shows that there is less spending from the government. According to COSTECH (2005b:19), for the period of ten years (1995–2004) the survey report indicated that the contribution from government was only 14% , while the contribution from foreign sources was 51%. In addition to that several other reports indicate that the country is heavily depending on foreign funding sources to conduct R&D activities.

5.2.1 Gross Expenditure on Research and Development (GERD)

The most commonly used and acceptable indicator to track research and innovation investment injected to R&D internationally is gross domestic expenditure on research and development (GERD) expressed in purchasing power parity (PPP$) and as a percentage of gross domestic product (GDP) dedicated to R&D undertakings (UIS,2018). “Purchasing power parity (PPP) is the currency exchange rate that equalizes the purchasing power of different currencies. This means that a given sum of money, when converted into US dollars at the PPP exchange rate (PPP dollars), will buy the same basket of goods and services in all countries" (UIS,2018).

Research and Innovation investment in many African countries remained below the targeted amount of 1% GDP as agreed by the African head of states in 1980 in the Abuja declaration. The gross domestic expenditure on research and development (GERD) in Tanzania remained lower in comparison with several countries in Africa in spite of the long history of science pre and post-independence administration. The data extracted from AU-NEPAD (2014) shows that in 2010 GERD was only 0.38% of the GDP (Table 5.1 below). Expressed as a percentage of GDP, Tanzania's R&D intensity is far less than the neighbouring country Kenya that spent 0.79% of GERD of GDP in 2010 followed by South Africa with GERD of about 0.76% of the GDP in the same year. The data shows that during the same year investment of Tanzania in R&D was the lowest when compared with Mozambique (0.42%) and Uganda (0.48%) in spite of being a politically stable country compared to Mozambique and Uganda. However, the most recent data from the UNESCO Institute for Statistics (UIS, 2018) shows an increase in 2013 to about 0.53% of GDP. The share of GERD as a percentage of the GDP in Sub-Saharan Africa was constant at 0.4% in 2007, 2009, 2011 and 2013, which was a little bit lower than Tanzania's GERD in 2013. Figure 5.1 below depicts the shares of world R&D expenditure (GERD) by region, 2007, 2009, 2011 and 2013.

Table 5.1: Gross Domestic Expenditure on Research and Development (GERD) for selected countries, 2013 or latest year available

Countries	Survey year	GERD % of GDP	GERD (PPP $ M)	GERD per Capita (PPP$)
Tanzania*	2010	0.38	316.86	7.64
Tanzania*	2013	0.53		12.42
Mozambique	2010	0.42	83.63	3.78
Uganda	2010	0.48	220.86	7.33
Senegal	2010	0.54	130.50	11.54
South Africa	2013	0.72	4021.30	92.79
Kenya	2010	0.79	652.00	19.54
*Partial data; Data source: UNESCO Institute for Statistics, February 2018				

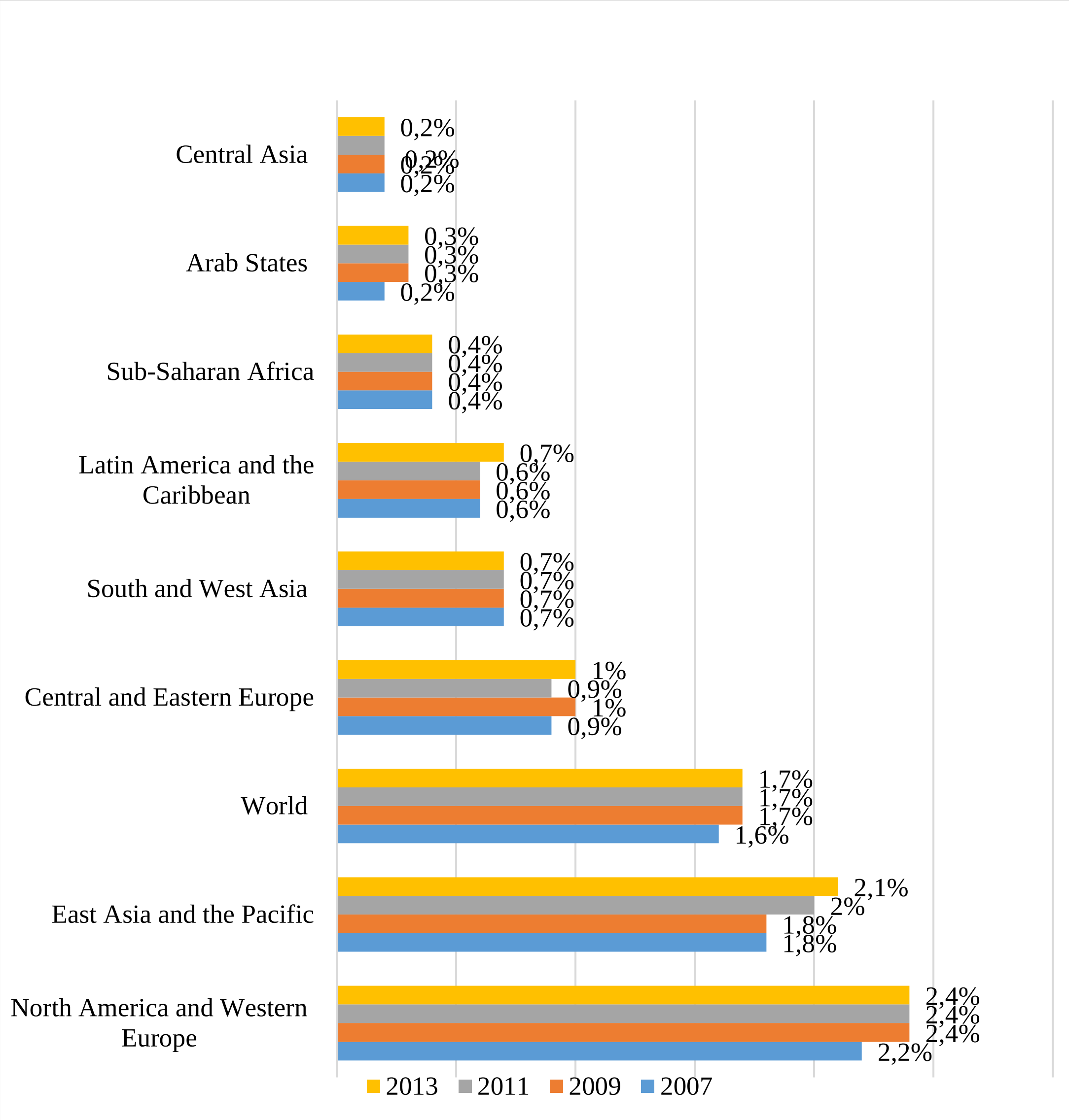

Figure 5.1: Shares of world R&D expenditure (GERD) by region, 2007, 2009, 2011 and 2013

Figure 5.2 below illustrates an increase in Tanzanian R&D intensity over ten years (2004–2013), from 0.2% GERD of GDP to 0.5% in 2013 (COSTECH, 2005b; UIS, 2018). Under the NEPAD agreement, it was endorsed that member states should increase the R&D intensity to 1% of the GDP by 2008. The country is many years behind to accomplish the target. The Tanzanian R&D survey that was conducted in 2005 revealed that some of R&D institutions did not receive research funding for several years (COSTECH, 2005b). That means the institutions were dormant or conducted research activities financed by external sources. The survey report showed that for the scope of 10 years (1994–2004), the average R&D expenditure sourced from abroad was about 51%, while that from the government was only 14%, and the rest came from privately owned (31%) and domestic sources (4%), as Figure 5.2 below depicts.

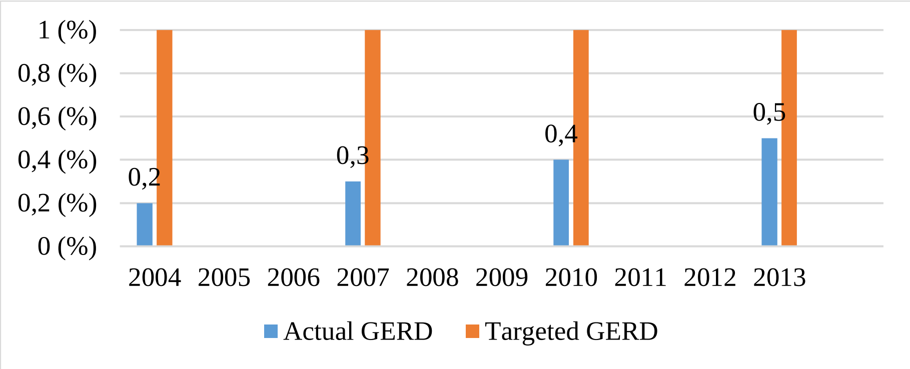

Figure 5.2: The Tanzania GERD as a % of GDP from 2004–2013

Data source: COSTECH, 2005 and UNESCO Institute for Statistics, 2018

5.2.2 GERD by type of R&D

Expressed as a percentage of GERD, more funds were expended on applied research (70.4%) followed by basic research (19%) while experiment and development research intensity was only 10.6% of gross expenditure in the year 2010 (Figure 5.3 below). The higher concentration on applied research in Tanzania could be simply explained by the emphasis on research undertaking to solve specific underlying challenges in the country. However, this cannot sufficiently be explained on the basis of the available data and hence requires more investigation. It was also noted that Uganda (43%) and South Africa (48.8%) GERD concentrated more on applied research during the year 2010 and 2014 respectively.

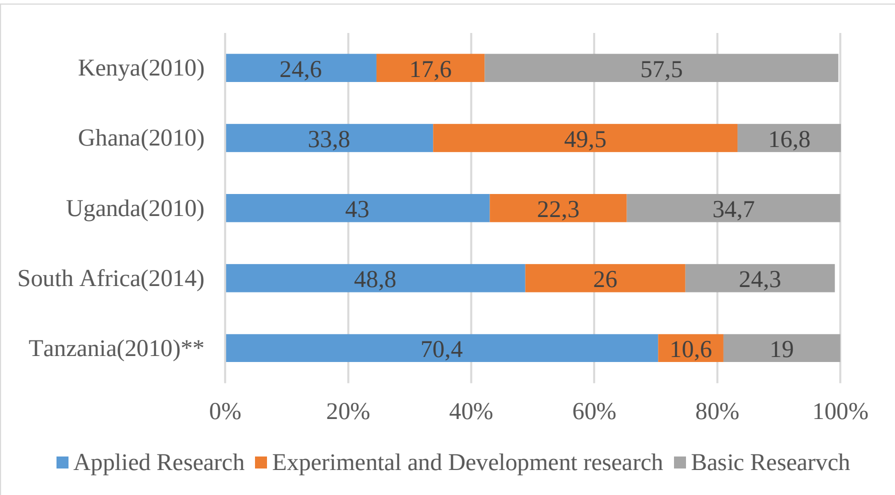

Figure 5.3: Share of GERD by type of R&D (Percentage) for selected countries, 2014 or latest year available

**UNESCO Institute for Statistics estimation

Data source: UNESCO Institute for Statistics, February 2018

5.2.3 Source of funding

Tanzania is among several Africa countries (excluding South Africa) which depends heavily on external sources of funds in supporting its research activities. The data extracted from the UNESCO Institute for Statistics (UIS, 2018) shows that in 2010, 42% of Tanzania's investment in R&D was from foreign sources compared to Uganda (57.2%) and Kenya (47.1%. The results from Figure 5.4 also show that the proportion of Tanzania's GERD originated from the business enterprise was negligible (0.1%) when compared with the neighboring East African countries of Uganda and Kenya which had 13.7% and 4.3% of their GERD originated from the business enterprise respectively. The low contribution of business sector to research could be due to a possible under-coverage of this sector in the survey. However, it is more likely that these figures do indicate the very low contribution of the business sector to R&D in the country. South Africa is one of the African countries with the high proportion of GERD (41.4%) originated from the business enterprise during 2013. Generally, it was noted that the proportion of GERD from the business enterprise is higher in developed countries than in developing countries. The status of public-private partnerships (PPPs) in research and scientific cooperation in Tanzania is insignificant. The contribution of the business sectors in Tanzania's GERD needs to be strengthened in order to attain a sustainable research and innovation investment in the country.

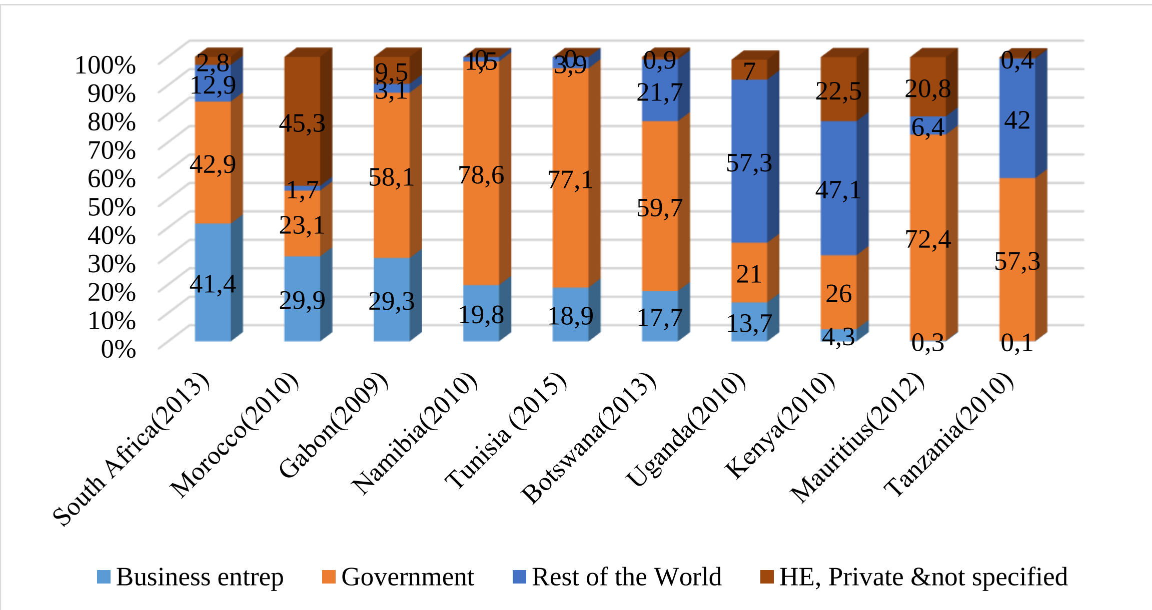

Figure 5.4 GERD percentage by source of funds for selected countries, 2015 or latest year available

Data source: UNESCO Institute for Statistics, February 2018

The R&D survey report (COSTECH, 2005b:19) showed that the government of Tanzania contributed only 14% of funding to overall investment in R&D, while the contribution from foreign sources was 51%, other sources (31%) and 4% from domestic sources for the period of 10 years, 1995–2004.

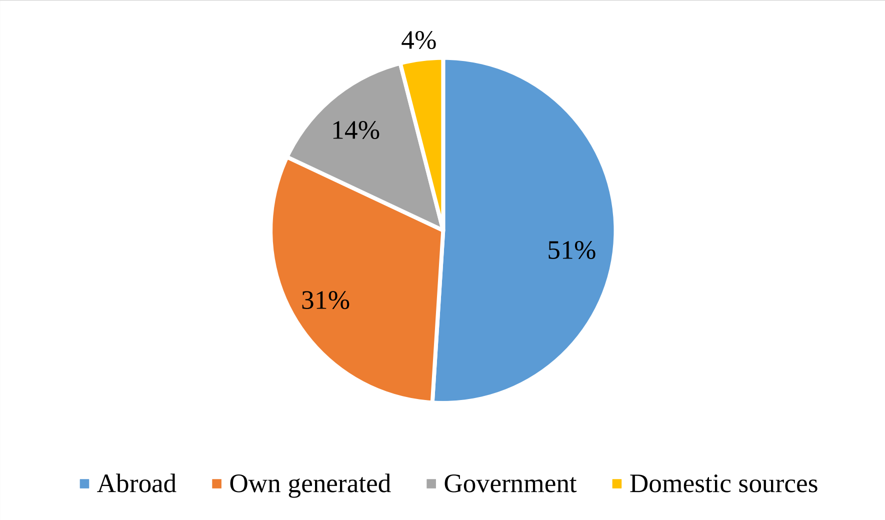

Figure 5.5: The proportion of total R&D expenditure by source of funding, 1995–2004

Source: COSTECH (2005b).

The proportion of funding from the government injected in the R&D expenditure increased from 37.7% in 2000 to 57.5% in 2010 (COSTECH, 2005b). In 2004 and 2007 the funding from the government sources were 61.4% and 60.6% respectively as Figure 5.6 below illustrates.

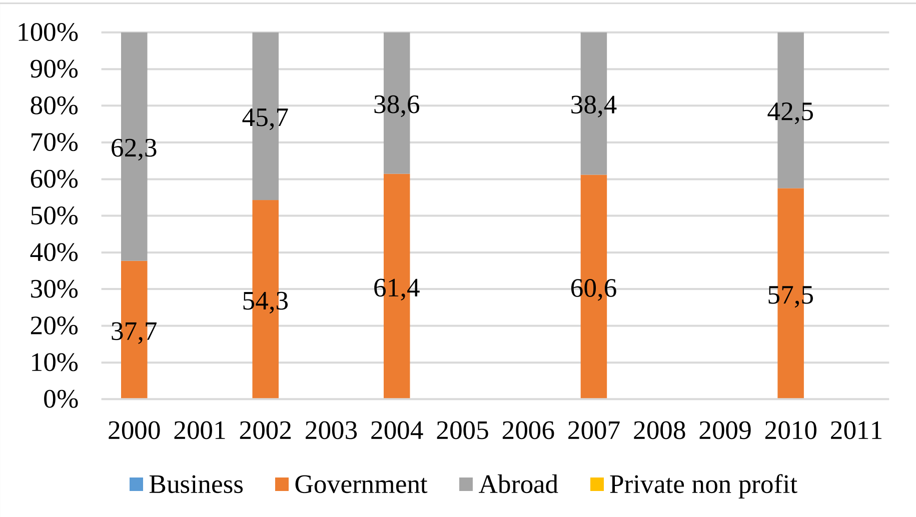

Figure 5.6: Tanzania GERD by source of funds, 2000–2010

Source: COSTECH, 2005b and UNESCO Institute for Statistics, 2018.

The share of research funding from abroad in the Tanzanian R&D expenditure was still high at the rate of about 42.5% in 2010. Nevertheless, in 2004 and 2007 the contribution from foreign sources were 38.6% and 38.4% respectively, as Figure 5.7 above illustrates. In addition to that, the UNESCO science report notes that most research projects in Tanzania are largely donor-financed with donor funds ranging from 52% to 70 % of the total GERD (UNESCO, 2015:560).

In the African Research Universities Alliance (ARUA) presentation it was also revealed that 80% of the R&D expenditure in 2017 for the University of Dar es Salaam, which is the oldest and largest university in Tanzania, was from foreign sources and the rest were from the government (8%), COSTECH (10%) and the private sector (2%) (UDSM, 2018). Scientific articles with funds acknowledgment in the WoS with an affiliation of Tanzanian institutions from 2010–2017 show that only 2% of publications received financial support from the government. The major funders reported are the Wellcome Trust, the Gates Foundation, the European Union, Sida, USAID, the National Institute of Health, Danida, the Swiss National Science Foundation, National Science Foundation, the UK Medical Research Council, World Health Organization and the German Academic Exchange Service (DAAD) (WoS, 2018).

The government of Tanzania through COSTECH in 1995 established the National Fund for Advancement of Science and Technology (NFAST) to ensure availability and reliable financial support dedicated to science, technology and innovation activities in the country. NFAST sources of funds are the parliamentary budget allocation from the government and from the public and private development partners (URT, 1986b). Despite having special funds dedicated to STI activities in the country, the R&D survey report showed that the government of Tanzania contributed only 14% while the foreign source's contribution was 51% for the whole period of 10 years (1995-2004) COSTECH (2005b:19). "The small contribution from government funding is an indication that research and development agendas are driven by others and not by the government policy and plans or researchers' ......" (Mouton et al., 2008:248). Well-developed S&T institutional and legal frameworks in Tanzania needs substantial research investment in order to support and stimulate R&D programs. The COSTECH's research grants manual stipulates supporting two research calls for proposals annually (January and July) COSTECH (2015:9), however, from 2012-2016 only four-research calls for proposals were advertised and granted. Generally, COSTECH does not perform its mandate efficiently to support S&T activities in the country simply because of insufficient budget allocation and funds disbursement from the treasury. In that regards R&D activities in Tanzania to a large extent depends on foreign funding.

In 2016, COSTECH received another source of funding through the Telecommunications Track Monitoring System (TTMS) in which 0.02% of the levy from internationals calls is disbursed to the NFAST account every month. If the flow of the TTMS funds to the NFAST account is maintained and topped up with the parliamentary budget allocation for research, it could ensure higher volumes of R&D funding in the country. COSTECH also mobilizes support for research and innovation with partners such as the National Research Foundation (NRF) - South Africa; the Danish International Development Agency (Danida); the Swedish International Development Agency (Sida), the Department for International Development of the United Kingdom (DfID). The other research partners are the Centre for Scientific and Industrial Research (CSIRO) in India; NRF South Korea; the United States Aid

Agency (USAID); the African Agricultural Technology Forum (AATF); the Australian Centre for International Agricultural Research (ACIAR) and so forth. In addition to the NFAST research-funding source, the government agencies and ministerial departments also mobilize resources for research and innovation activities through a network of partnerships.

Enormous dependence on foreign funding for R&D program in a country could result in the implementation of R&D projects that are not geared to solve the prevailing challenges of a particular country. For instance, Tanzanian research programs in R&D institutions are guided by the national research agenda of the country as the roadmap which is reviewed periodically depending on the need. The current research priority agenda in Tanzania was formulated in 2015. As described above, the huge dependence of R&D program to the funding from abroad could compromise the implementation of the research agenda in the country since conducted research which is donor-driven could be directed to solve their agenda. It is important for developing countries, in particular, to substantially support the R&D programs based on internal funding sources. For instance, in 2010, the government of Kenya managed to accelerate the R&D intensity by increasing the gross public expenditure on R&D to 0.78% and rise to 0.98% GERD of GDP (AU-NEPAD, 2014:25). Therefore, it is the high time for Tanzania to strategies in order to raise the R&D investment for social-economic of the country.

5.3 Survey data: Funding of science

In this section of the chapter we report on the factors that could impact the performance of researchers in Tanzania based on our analysis of survey data and the interviews with selected respondents of the Young Scientists' project in Africa. The first part of the survey was conducted through a semi-structured questionnaire, followed by the interviews with selected respondents to gain more insight into the factors responsible for influencing the performance of researchers and career development of scientists in the country. The survey questionnaire considered several dimensions to capture factors that influence the research performance and career development of the scientists. These dimensions are educational background, employment category, research output, funding, international mobility, collaboration, mentoring, demographic background and working conditions. The follow up interviews for selected respondents were also conducted to get deep insight into the factors influencing the performance of scientists in Tanzania.

Generally, this chapter analysed sources of research funding and the general trends of research funding across the scientific fields. Additionally, the chapter also analysed the factors influencing the performance of researchers in the country as explained above. The specific questions, sub-themes, and themes that have been addressed in this chapter are shown in Table 5.2 below.

Table 5.2: Themes, sub-themes, and research questions for the analysis and findings of the survey and qualitative analysis

Main themes	Sub-themes	Research questions	Methods
Research and innovation investment	i. National and international research funding.	• Who are the top research funders in Tanzania? • What are the main trends in government funding from 1995 to 2013?	Bibliometric indicators, survey and interviews
	ii. Trends in terms of investment by scientific fields.	• What are the main trends in terms of investment by scientific field?	
Scientists' working environment	i. Main factors influencing performance of scientists.	• What are the main factors that influence the research performance of scientists in Tanzania? • How are these factors related to access to resources, networks and collaborations, mentoring and intentional support for the young scientists in Tanzania?	Survey and interviews

5.3.1 National and international research funding

Out of 82 Tanzanian scientists who completed the questionnaire, 70 (85.4%) responded to the question "on proportion of funding obtained from national sources". When the respondents who had received funding (for their scientific field) were cross tabulated with the proportion of funding obtained from <u>national</u> sources (see Table 5.3 below), it was found that, in all scientific fields almost a half of the proportion of respondents (44.3%, N = 31) were most likely to have not received any funding from the national sources. The results also shows that nearly three quarters of respondents (71.4%) in all the scientific fields were most likely to have merely received 20% or less funding from national sources in the three years preceding the survey.

The results also shows that the proportions of respondents from the natural sciences, health sciences and agricultural sciences who received 100% funding from the national sources were 13.0%, 10.0% and 7.1% respectively. It was also noted that the respondents in engineering and applied technologies and the social sciences were the least likely to have received funding from national sources.

Table 5.3: The proportion of funding obtained from the national sources

Proportion of funding obtained from national sources		Fields					Total	Cumm.. %
		Natural sciences	Agricultural sciences	Engineering and applied technologies	Health sciences	Social sciences		
0%-20%	N	14	10	4	16	6	**50**	71.4%
	%	61.0%	71.4%	100.0%	80.0%	66.6%	**71.4%**	
21%-50%	N	3	2	0	2	1	**8**	82.8%
	%	13.0%	14.3%	0.0%	10.0%	11.1%	**11.4%**	
51%-80%	N	3	1	0	0	2	**6**	91.4%
	%	13.0%	7.1%	0.0%	0.0%	22.2%	**8.6%**	
81% - 100%	N	3	1	0	2	0	**6**	100.0%
	%	13.0%	7.1%	0.0%	10.0%	0.0%	**8.6%**	
Total	N	**23**	**14**	**4**	**20**	**9**	**70**	
	%	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	

When the respondents who had received funding (according to their scientific fields) were cross tabulated with the proportion of funding obtained from <u>international</u> sources (see Table 5.4 below), it was found that, in all five scientific fields more than half of the respondents (54.5%, N = 42) were most likely to have received 100% funding from international sources. The results also show that more than three-quarters of respondents (77.1%) in all the scientific fields were most likely to have received 80% or more funding from international sources in the three years preceding the survey. The results further show that the respondents in the field of health sciences were most likely to have received 100% international funding (68.2%), while the proportion of respondents who received 100% in the natural science, engineering and applied technologies, agricultural sciences, and the social sciences were 52.0%, 50%, 46.7%, and 45.5% respectively.

Table 5.4: The proportion of funding obtained from international sources.

Proportion of funding obtained from international sources		Fields					Total	Cumm. %
		Natural sciences	Agricultural sciences	Engineering and applied technologies	Health sciences	Social sciences		
0%-20%	N	4	1	0	0	1	**6**	7.8%
		16.0%	6.7%	0.0%	0.0%	9.1%	**7.8%**	
21%-50%	N	1	1	0	1	1	**4**	13.0%
	%	4.0%	6.7%	0.0%	4.5%	9.1%	**5.1%**	
51%-80%	N	4	4	1	3	3	**15**	32.5%
	%	16.0%	26.6%	25.0%	13.6%	27.3%	**19.5%**	
	N	16	9	3	18	6	**52**	100.0%

81-100%	%	64.0%	60.0%	75.0%	81.8%	54.6%	**67.5%**	
Total	**N**	25	15	4	22	11	77	
	%	**100.0%**	**100.0**	**100.0**	**100.0%**	**100.0%**	**100.0%**	

5.3.2 The distribution of funding received across the scientific fields

When cross-tabulated with scientific fields (see Table 5.6 below), it was found that those respondents in the natural sciences are proportionately most likely to have received funding during the three years prior to the survey. It was also observed that the likelihood to have received funding in the health sciences, agricultural sciences and in the social sciences is the same. Almost two-thirds of respondents in the three fields indicated that they have received funding. The respondents in the fields of engineering and applied technologies were the least likely to have received research funding in the three years prior the survey.

Table 5.5: Receipt of funding by scientific field

Receipt of funding		Natural sciences	Agricultural sciences	Health sciences	Social sciences	Engineering & applied technologies	**Humanities**	**Total**
No	N	8	8	14	7	4	**1**	**42**
	%	22.9%	34.8%	36.8%	36.8%	50.0%	**100.0%**	**33.9%**
Yes	N	27	15	24	12	4	**0**	**82**
	%	77.1%	65.2%	63.2%	63.2%	50.0%	**0.0%**	**66.1%**
Total	**N**	**35**	**23**	**38**	**19**	**8**	**1**	**124**
	%	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

When the respondents who had received funding, were cross-tabulated with scientific fields (see Table 5.6 below), again it was found that, proportionately, the respondents who are trained in the natural sciences were the most likely to have received the most funding (33.3%) in the highest funding category (more than US$250 000), followed by the agricultural sciences (27.3%) and the health sciences (24.3%). Additionally, it was also observed that in the second highest funding category (US$100 001–250 000) the respondents in the health sciences were most likely to have received the highest amount of funding (35.7%), followed by the natural sciences (28.6%), and agricultural (14.3%) and social sciences in the first three fields (14.3%).

In the third funding category ((US$ 50 000–75 000) results show that, the respondents in the health sciences are most likely to have received the highest amount of funding among the fields (41.67%), followed by the respondents in the natural sciences, which received 26.1% .

Table 5.6: Amount of funding received by scientific field

Amount in US$		Field						Total
		Natural sciences	Health sciences	Agricultural sciences	Engineering & applied technologies	Social sciences	Humanities	
< 50 000	N	10	9	1	0	4	**0**	**24**
	%	41.67%	37.5%	4.17%	0.0%	16.67%	**0.0%**	**100.0%**
51 000–100 000	N	6	10	3	0	4	**0**	**23**
	%	26.01%	41.67%	12.5%	00.0%	17.39%	**0.0%**	**100.0%**
100 001–250 000	N	4	5	2	1	2	**0**	**14**
	%	28.6%	35.7%	14.3%	7.1%	14.3%	**0.0%**	**100.0%**
> 250 000	N	11	8	9	3	2	**0**	**33**
	%	33.3%	24.3%	27.3%	9.1%	6.1%	**0.0%**	**100.0%**
Total	**N**	**27**	**24**	**14**	**4**	**9**	**0**	**78**
	%	**34.6%**	**30.8**	**17.9%**	**5.1%**	**11.5%**	**0.0%**	**100.0%**

5.3.3 Funding agencies from which respondents received research funding over the three years 2014–2016

The findings from the secondary survey of Tanzanian respondents show that the top international research funding agencies between 2014 to 2016 were the Bill and Melinda Gates Foundation, the Swedish International Development Agency, and the Department for International Development. The other foreign funding organisations were the Flemish Inter-University Council, the US National Institutes of Health, NORAD, the Wellcome Trust, the United States Agency for International Development, the European Union and the Grand Challenges Canada. The Tanzania Commission for Science and Technology was mentioned as the most frequent national funding agency in the country, as Table 5.7 displays below. However, the findings should be interpreted with caution, since the survey data are based on self-reporting. Additionally, the survey sample size is too small to draw very strong conclusions. However, it is noteworthy that the results from the survey provided a general picture of the research funding landscape in the country which confirms the scientometric data.

Table 5.7: The funding agencies from which respondents received research funding (2014–2016)

Funding agency	Number of projects	Percentage (%)
Bill and Melinda Gates Foundation	5	3.7
Sida	5	3.7
DFID	4	2.8
Flemish Inter University Council	4	2.8
National Institutes of Health	4	2.8
NORAD	4	2.8
Wellcome Trust	4	2.8
COSTECH	3	2.1
USAID	3	2.1

Funding agency	Number of projects	Percentage (%)
European Union	2	1.4
Grand Challenges Canada	2	1.4
African Elephant Fund	1	0.7
Alliance Green Revolution Africa	1	0.7
Council for the Development of Social Science Research in Africa	1	0.7
Deutsche Forschungsgemeinschaft	1	0.7
Doris Duke Charitable Foundation	1	0.7
Foundation for African Real Estate Research	1	0.7
GIZ	1	0.7
Global fund	1	0.7
Government: Germany	1	0.7
Government: Norway	1	0.7
INASP	1	0.7
International Atomic Energy Agency	1	0.7
International Growth Centre	1	0.7
Ministry of Foreign Affairs, Finland	1	0.7
National Library of Medicine NIH	1	0.7
National Science Foundation	1	0.7
Natural Environment Research Council	1	0.7
PAMS Foundation	1	0.7
PATH Malaria Vaccine Initiative	1	0.7
Royal Society of Chemistry	1	0.7
SIRIUS-UK	1	0.7
Society of Conservation Biology	1	0.7
SUS	1	0.7
Swiss National Science Foundation	1	0.7
The European Academy of Dermatology and Venereology	1	0,7
The Leverhulme Trust	1	0.7
The Swedish Research Council Formas	1	0.7
UK Medical Research Council	1	0.7
UNDP	1	0.7
University of Antwerp - BE	1	0.7
University of California, Davis - US	1	0.7
Unspecified	1	0.7
VINNOVA	1	0.7
Western Indian Ocean Marine Science Association	1	0.7
WHO	1	0.7
World Bank	1	0.7
World Vision International	1	0.7

Data source: Young Scientists' Project in Africa (YSA) research project, 2016

5.4 Funding acknowledgements

Our bibliometric analysis on Tanzanian authored papers (detailed discussions in Chapters 7 and 8) also gathered data on the Web of Science field on "funding acknowledgement". The results of these analyses for the period of ten years (2005-2016) show that the top foreign research funding organisation in Tanzania include the following organisations: The Wellcome Trust, the Bill and Melinda Gates Foundation, the UK Medical and Research Council, the European Union, the US National Institute for Health, and the Swedish International Development Agency (Table 5.8). The other funding organisations are the US National Institute of Allergy and Infectious Diseases, the Swiss National Science Foundation, the United States Agency for International Development, the National Science Foundation, and the Danish International Development Agency. The Tanzanian national bodies are the Government of Tanzania, the University of Dar es Salaam, Sokoine University of Agriculture, the Ifakara Health Institute and the Tanzania Wildlife Research Institute. The top research funding agencies are from the United States, the United Kingdom and the European countries in general. This could be attributed to high-level collaborative research of Tanzania with the US, the UK, and the European countries. However, again the findings on the research funding agencies in Tanzania should be interpreted with caution, simply because there are some authors who not necessarily acknowledge the financial supporters of their research outputs. It should also be taken into account that the publication data from the WoS is not comprehensive, covering all the research publications from Tanzania for the window of the study period (2005–2016). Therefore, some research funders could have had been left out.

But again, it is noteworthy that, the findings from the survey painted more or less the same picture as the bibliometric analysis of the funding acknowledges (Table 5.7) where the top international research funding agencies between 2014 to 2016 were the Bill and Melinda Gates Foundation, the Swedish International Development Agency, and the Department for International Development. The other foreign funding organisations were the Flemish Inter-University Council, the US National Institute of Health, NORAD, the Wellcome Trust, the United States Agency for International Development, the European Union and the Grand Challenges Canada. Again, the bibliometric findings indicate that the Tanzania Commission for Science and Technology was mentioned as the most frequent national funding organisation in the country.

Table 5.8: Top research funding agencies in Tanzania from 2005–2016

Funding agency	Number of projects
Wellcome Trust	396
Bill and Melinda Gates Foundation	380
Medical Research Council	332

Funding agency	Number of projects
European Union	292
National Institutes of Health	286
Sida	135
NIH	108
DANIDA	89
Swiss National Science Foundation	74
USAID	70
National Science Foundation	69
Biotechnology and Biological Sciences Research Council	59
World Health Organization	58
Natural Environment Research Council	54
Economic and Social Research Council	47
Government of Tanzania	46
UK Department for International Development	38
National Institute of Mental Health	36
Ifakara Health Institute	27
University of Dar es Salaam	24
Sokoine University of Agriculture	12
Tanzania Wildlife Research Institute	12

5.5 Impact of the lack of funding on careers of scientists

One of the objectives of this study was to determine the main factors that influence the research performance of scientists in Tanzania as reported in the survey which formed part of CREST's study on Young scientists in Africa. In order to identify the main challenges which influence the research performance that scientists in the country face, respondents were asked to show to what extent (not at all; to some extent; or to a large extent) 10 predetermined factors may have influenced their research performance as academicians or scientists negatively. To allow comparisons between two age group categories (40 years or younger, and 41 years and above) , response categories were collapsed to create a binary variable entailing two response categories: (1) 'not at all'; and (2) 'at least to some extent' (a combination of 'to a large extent' and 'to some extent'). The survey produced unsurprising results (see Table 5.9), indicating that the lack of research funding was identified by all respondents, regardless of the age group, as posing the biggest challenges facing their research performance followed by the lack of funding for research equipment.

Table 5.9: Respondents' perceptions of the impact of 10 factors on their careers

Challenges to their careers	Overall rank	Rank by age	
		40 and younger	41 and older
Lack of research funding	1	1	1
Lack of funding for research equipment	2	2	2
Lack of training opportunities to develop professional skills	3	4	4
Lack of mentoring and support	4	3	5
Balancing work and family demands	5	6	3
Lack of mobility opportunities	6	5	7
Lack of access to library and/or information sources	7	8	6
Job insecurity	8	7	8
Limitation of academic freedom	9	9	9
Political instability	10	10	10

- Of the 142 cases who responded to the survey questionnaire, when the two age categories of respondents (40 years or younger, and 41 years and above), were cross tabulated with the lack of research funding if it has impacted negatively on the career, it was found that 116 (82%) responded to the question, "Has the lack of research funding impacted negatively on your career as an academic or scientist?", and 26 respondents did not provide any response to the question. To allow comparisons between the two age group categories (40 years or younger, and 41 years and above), response categories were collapsed to create a binary variable entailing the two response categories (1) 'not at all'; and (2) 'at least to some extent' (a combination of 'to a large extent' and 'to someextent'). Nearly nine young scientists out of ten indicated that the lack of research funding had anegative impact on their careers (see Table 5.10, Figures 5.7 and 5.8). This is not a surprising results, simply because it reaffirms the previous findings by Gaillard et al., (2002).89.7% of respondents in the 40 years or younger category indicated that at least to some extent the lack of research funding had a negative impact on their careers as academics or scientists.
- 84% of respondents in the 41 years or older category also indicated that at least to some extent the lack of research funding had a negative impact on their careers as academics or scientists.
- 86% of all respondents, regardless of the age group, indicated that at least to some extent, the lack of research funding had a negative impact on their careers as academics or scientists.
- 35% of respondents who indicated that at least to some extent the lack of research funding had a negative impact on their careers as academics or scientists were in the 40 years or younger category.

- 65% of respondents who indicated that at least to some extent the lack of research funding had a negative impact on their careers as academics or scientists, were in the 41 years or older category.
- Disaggregation of the lack of research funding by the two age groups of respondents showed no significant differences.

Table 5.10: Lack of research funding by age interval

Age category			Lack of research funding		Total
			Not at all	At least to some extent	
Age category	40 or younger	Count	4	35	39
		Expected count	5.4	33.6	39.0
		% within age category	10.3%	89.7%	100.0%
		% within lack of research funding	25.0%	35.0%	33.6%
		% of Total	3.4%	30.2%	33.6%
	41 or older	Count	12	65	77
		Expected count	10.6	66.4	77.0
		% within age category	15.6%	84.4%	100.0%
		% within lack of research funding	75.0%	65.0%	66.4%
		% of Total	10.3%	56.0%	66.4%
Total		Count	16	100	116
		Expected count	16.0	100.0	116.0
		% within age category	13.8%	86.2%	100.0%
		% within lack of mentoring and support	100.0%	100.0%	100.0%
		% of total	13.8%	86.2%	100.0%

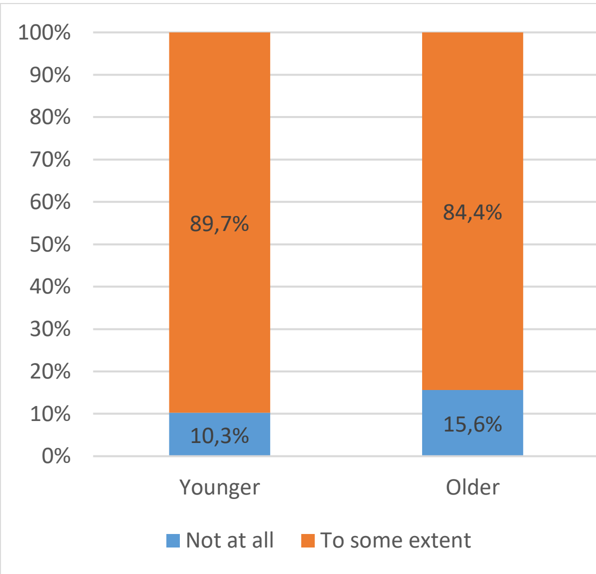

Figure 5.7: Lack of research funding by age groups

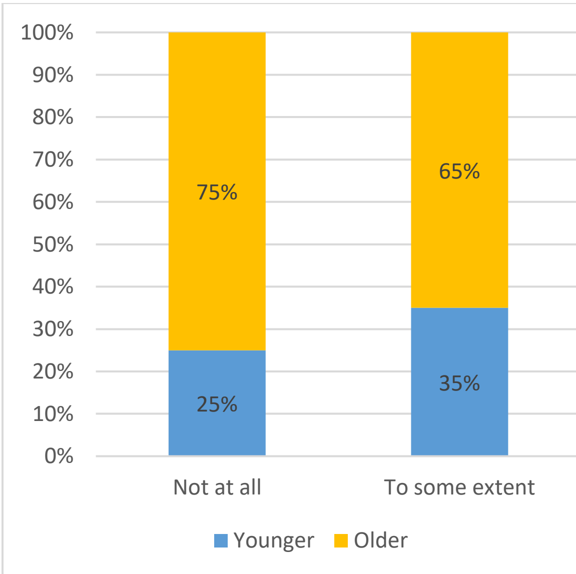

Figure 5.8: Proportion of lack of research funding in combined age group

5.6 Lack of funding for research equipment

Of the 142 scientists who responded to the survey questionnaire, it was found that 113 (79.6%) responded to the question, "Has the lack of funding for research equipment impacted negatively on your career as an academic or scientist?". Of the respondents 29 did not respond to the question. To compare the two age groups (40 years or younger, and 41 years and above), response categories were collapsed to formulate a binary variable consisting of the two response categories (1) 'not at all'; and (2) 'at least to some extent' (a combination of 'to a large extent' and 'to some extent'). Almost 85% of the young scientists showed that the lack of funding for research equipment had a negative impact on their careers (see Table 5.11, Figures 5.9 and 5.10).

- 85% of respondents in the 40 years or younger category indicated that at least to some extent the lack of funding for research equipment has impacted negatively on their careers as academics or scientists.
- 77% of respondents in the 41 years or older category indicated that at least to some extent the lack of funding for research equipment has impacted negatively on their careers as academics or scientists.
- 80% of all respondents, regardless of the age group, indicated that at least to some extent the lack of funding for research equipment has impacted negatively on their careers as academics or scientists.
- 37% of respondents who indicated that at least to some extent the lack of funding for research equipment has impacted negatively on their careers were in the 40 years or younger category.
- 63 % of respondents who indicated that at least to some extent the lack of funding for research equipment has impacted negatively on their careers, were in the 41 years or older category.
- Disaggregation of the lack of funding for research equipment by the two age categories of respondents, showed no significant differences.

Table 5.11: Lack of funding for research equipment by age groups

			Lack of funding for research equipment: Not at all	Lack of funding for research equipment: At least to some extent	Total
Age category	**40 or younger**	Count	6	33	39
		Expected count	7.9	31.1	39.0
		% within age category	15.4%	84.6%	100.0%
		% within lack of funding for research equipment	26.1%	36.7%	34.5%
		% of total	5.3%	29.2%	34.5%
	41 or older	Count	17	57	74
		Expected count	15.1	58.9	74.0
		% within age category	23.0%	77.0%	100.0%
		% within lack of funding for research equipment	73.9%	63.3%	65.5%
		% of total	15.0%	50.4%	65.5%
Total		Count	23	90	113
		Expected count	23.0	90.0	113.0
		% within age category	20.4%	79.6%	100.0%
		% within lack of funding for research equipment	100.0%	100.0%	100.0%
		% of total	20.4%	79.6%	100.0%

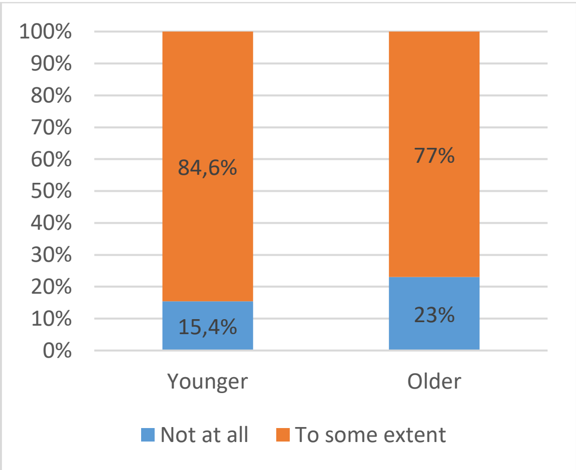

Figure 5.9: Lack of funding for research equipment by age groups

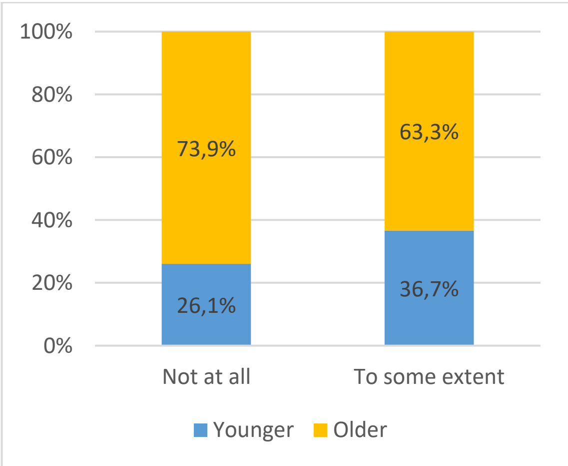

Figure 5.10: Lack of funding for research equipment in combined age groups

5.7 Discussion

The findings from the survey analysis of researchers' responses indicate that lack of research funding remains the major challenge facing scientists in all age groups in the country. There are few national research funding sources in the country and researchers rely more on external research funding. The findings from the survey suggest more or less the same picture as indicated in the bibliometric results above. The Tanzania Commission for Science and Technology was indicated as the most frequent national funding agency in the country. Triangulation of the findings on the top research funding agencies in Tanzania from the survey and bibliometric indicators, and the interviews suggest more or the same results. This reaffirms the previous findings from other sources (COSTECH, 2005b:19; Mouton, 2010; UNESCO, 2015:560) that the country still heavily depends on foreign sources to fund research activities.

The findings also revealed that scientists from the natural sciences, agricultural sciences and health sciences fields are most likely to have secured higher amounts of funding from both the national and international sources. The social sciences, engineering and applied technologies fields are less likely to receive research funding.

The qualitative study intended to triangulate and provide explanations for the factors negatively influencing the research performance of scientists. The interviews with selected scientists in Tanzania suggested that the main factors influencing the performance of scientists in the countries were research funding, working environment/research facilities, mentorship, lack of training opportunities to develop professional skills, researchers mobility and teaching work overload. The interview results suggested that inadequate research funding is the most important factor that has a negative impact on the research performance of scientists in Tanzania. The findings from the interviews were not surprising, simply because previous reports also indicate the research funding is one of the major challenges facing the R&D institutions in Tanzania.

Moreover, the results from the secondary survey data on the factors negatively influencing the research performance of the scientists in Tanzania reaffirmed the findings from the interview for selected respondents in the Young Scientists in Africa research project. The survey findings also showed that the lack of research funding and funding for research equipment were the biggest challenges for the performance of both young and senior scientists in the country. As shown in the results section, about 90% of the young scientists showed that the lack of research funding had a negative impact on their careers. In addition about 86% of respondents, indicated that the lack of research funding had a negative impact on their careers as academics or scientists. The lack of funding for research equipment was also identified to have a negative impact on the research careers of 85% of the young scientists, while 80%

% of all respondents, regardless of the age groups, indicated a concern regarding the lack of funding for research equipment for an impact on their careers.

The qualitative analysis of this study through the interviews notes the experience of scientists on securing research funding as quoted During the interviews, a young scholar, who is a beneficiary of research funding in the last three years noted that:

> I think research funding is quite challenging. We've got a couple of global funding schemes and research programmes…… Most times, it has to be in collaboration with a Western partner or some other universities that are more advanced or have better reputations of doing funded research. Most of the time we have to tweak our research concepts or proposal to fit with their research agenda.

Another scientist during the interview expressed the concern regarding the dependence on and sustainability of foreign research funding by noting that:

> But the funding from other external organization is possible. But I am just wondering how long shall we depend on external funding, because that's not sustainable.

The allocation of research funding, as stipulated by the policies and other regional agreements, is still inadequate to support research activities in the country. Inadequate research funding leads to little production of knowledge, products, processes and services. In this situation, the existing potential of the labour force in the R&D in the country is not fully utilised for the social and economic benefits of the country.

In support of this point, other previous surveys and interviews indicate that most funding disbursed by the government to R&D institutions is often spent on recurrent expenditure related to staff salaries and running costs, with little or no reserve for research activities and research infrastructure support (UNCTAD, 2015). For instance, in 2011 about 95.1% of funds allocated to agricultural R&D in the country, were spent for staff emoluments and operating costs, leaving only 4.9% for capital investment (UNCTAD, 2015). This reaffirm the interview response of one of the young scientists in this study, who noted that:

> [L]et's say like I want to publish in an open access journal where I need to pay for publication, my institution does not pay, that's not, they have limited budget. And that, they are using that budget for the operation costs … paying electricity, water, paying for the security.

Poor working environments and inadequate research equipment are also a concern which was mentioned to influence the performance of scientists negatively in most of the Tanzanian R&D institutions. Most of the R&D institutions have old and dilapidated research equipment and machines. The Tanzania Commission for Science and Technology, through the National Funds for Advancement of Science and Technology (NFAST), do support R&D institutions in terms of research facilities and equipment in a competitive manner through available research funding. However, the funding has always been too little to support the majority of R&D institutions in the country. Additionally, it was noted that some modern laboratory equipment for research activities are few or not available in the country.

For instance in 2012/2013 COSTECH supported the renovation and building of new research facilities for about 20 R&D institutions countrywide. However, the COSTECH research equipment calls are sporadic, simply because of inadequate of funding. It is the high time for the government to increase the allocation of funds through the national funds for Advancement of Science and Technology to facilitate research and infrastructure support for R&D institutions in the country.

The results also noted that there are too few of some laboratory machines for research in some R&D institutions. One of the young scientist from one of the big university in Tanzania during the interview expressed the shortage of laboratory equipment and the advantage of research mobility by saying that:

> In our University, although we do not have research funds, but also research equipment, like the big machines. I am a chemist. … all this equipment are not here in Tanzania. So by going abroad, you have this but you also have access to more research journals and education. So you should be able to update your information by going abroad.

5.8 Conclusion

Tanzanian research and innovation investment is still below 1% of the GDP the country. The Abuja declaration in 1980, the NEPAD agreement, and even the national research and development policy have not yet manage to increase the R&D spending to 1% of GDP. Tanzanian R&D investment increased from 0.38% in 2010 to about 0.53% of GDP in 2013. In spite of the slight increase in research investment, the spending on R&D institutions in the country is still heavily dependent on international funding sources. For several decades, a big portion of research funding was sourced from international agencies. The overdependence on external funding could result in the execution of foreign research agendas with little or no impact on solving the challenges facing the country. In recent years, an East Africa Community member state (Kenya) has set a good example by increasing R&D spending to close to 1% of the GDP. It is highly recommended that the Tanzanian government increase the budget allocation and disbursement for research funding to facilitate and accelerate science, technology and innovation activities in the country.

The availability of updated R&D investment data and other R&D indicators is one of the challenges facing the R&D system in the country. As shown above, the most recent R&D spending indicators in Tanzania were for the year 2013, simply because the most recently available R&D survey report in the country is for 2013/2014. It is essential to conduct R&D surveys regularly in order to monitor and evaluate the investment, capacity and outputs in the national R&D system.

The lack of funding is clearly the main challenge facing scientists in Tanzania. Although scientists showed that they could secure funding from both national and international sources, it is evident that scientists with big scholarly networks are more likely to attract and receive significantly higher amounts of funding from both national and international sources. The study also found that the majority of scientists (more than three quarters) who received international funding, are most likely to have received more than 80% of funding from international sources. On the other hand, the majority of scientists who indicated having received funding from the national sources, merely secured 20% or less funding from these national sources.

In general, scientists in the fields of natural, agricultural and health sciences received a big proportion of funding from both the national and international sources. The qualitative and survey results corresponded with the literature on difficulties in securing research funding for scientists, particularly by young scientists. The study recommends that more support should be provided to young scientists by their R&D institutions and national research funding agencies in the country, COSTECH in particular. Special research calls for young scientists should be formulated and administered to provide young scientists opportunities in their early career endeavours.

CHAPTER 6: HUMAN RESOURCES FOR S&T AND FACTORS AFFECTING RESEARCH PERFORMANCE

6.1 Introduction

The most recent information from the UNESCO Institute for Statistics shows the decline of the Tanzanian research and innovation capacity (UIS, 2018). Additionally, the studies by AU-NEPAD (2014:103) and AU – NEPAD (2019) indicated that the Tanzanian total R&D personnel headcount in the higher learning and the government research institutions was 5788 in 2010 and 6502 in 2013. In 2013, the proportion of R&D personnel was 69% in higher learning institutions and 31% in research institutions. The standard and common indicators used to evaluate the research and innovation capacity of a country include R&D personnel headcount (HC), researchers' HC, fulltime equivalent (FTE), level of education (ISCED), proportion of female personnel, research collaboration and so on.

As defined by the Frascati Manual (OECD, 2015:151)

> R&D personnel in a statistical unit include all persons engaged directly in R&D, whether employed by the statistical unit or external contributors fully integrated into the statistical unit's R&D activities, as well as those providing direct services for the R&D activities (such as R&D managers, administrators, technicians, and clerical staff). Researchers are professionals engaged in the conception or creation of new knowledge. They conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods (OECD, 2015:162).

Headcount (HC) refers to the actual number of people directly involved in or supporting R&D activities. This includes researchers, technicians and other personnel directly supporting R&D. Full-time equivalent (FTE) refers to the number of hours (in terms of person-years of effort) spent on R&D activities. This chapter report on the results of our analysis of the Tanzanian research and innovation capacity as outlined in Table 6.1 below.

Table 6.1: Framework outlining the main themes and sub-themes for the analysis and findings of survey and scientometrics.

Main themes	Sub themes	Research questions	Applied tools
Research and innovation capacity	Human resources base of Tanzania R&D institutions	• What are the features and size of the human resources base of Tanzania R&D institutions? • What are the main factors influencing the performance of scientists?	Scientometric indicators and R&D survey

6.2 Research capacity in Tanzania

The most recent report from AU – NEPAD (2019) shows that the number of R&D personnel headcount in the R&D institutions was 6502 in 2013. The proportion of R&D personnel in higher learning institutions and research institutions were 69% and 31% respectively (Table 6.2). The standard indicators used to assess the research and innovation capacity of a country include R&D personnel headcount (HC), researchers' HC, fulltime equivalent (FTE), education level (ISCED) and proportion of female personnel.

Table 6.2 Tanzanian R&D personnel HC by occupation and gender (2013)

R&D personnel by occupation	**Total**	**Government research institutions**	**Higher education institutions**
Total R&D personnel (HC)	6502	2013 (31%)	4489 (69%)
Researchers	3400(52%)	1318	2082
Technicians	1354(21%)	446	908
Support staff	1748(27%)	249	1499
Female	**2964**	**865**	**2099**
Researchers	1186	**429**	757
Technicians	725	246	479
Supporting staff	1053	190	863

Source: AU-NEPAD, 2019 and UIS, 2018.

Expressed as full-time equivalents (FTE), Table 6.3 shows that the Tanzania R&D human resource capacity was 2915.9 in 2013, which shows more or less the same R&D human capacity of 2928.6 in 2010. Table 6.3 also shows that the FTEs in the government research institutions (668.8) was almost a quarter of the total FTEs (2915.9) in the country while the FTEs in higher education was (2247.1 or nearly 75%) of the total FTEs.

Table 6.3 Tanzanian R&D personnel FTEs by occupation (2013)

R&D personnel by occupation	**Total**	**Government research institutions**	**Higher education institutions**
Total R&D personnel	2915.9	668.8	2247.1
Researchers	2067.3	366.3	1701
Technicians	299.2	129.4	169.8
Support staff	549.4	173.1	376.3
Female	708.6	178.2	530.4
Researchers	404.8	80.8	324
Technicians	64.1	17.0	47.1
Support staff	239.7	80.4	159.3

Source: AU-NEPAD, 2019

6.2.1 Tanzanian researchers HC by level of education (2010)

The most recent African Innovation Outlook III report (AU-NEPAD, 2019) shows that, in 2013, the largest proportion of researchers in R&D institutions in Tanzania hold master's degrees (39%) with only 25% holding a PhD qualification

Table 6.4: Tanzanian researchers by qualification (2013)

Researchers by level of education	Total	Government research institutions	Higher education institutions
Total	**3400**	**1318**	**2082**
Researchers (HC) ISCED 8 (Doctoral level)*	847 (25%)	-	-
Researchers (HC) ISCED 7 (Master's level)	1339(39%)	-	-
Researchers (HC) ISCED 6 (Bachelor's level) *	994(29%)	-	-
Researchers (HC) ISCED 5 (Diploma level)*	167(5%)	-	-
Researchers (HC) All other qualifications*	53(2%)	-	-
*The data excluding business enterprises			

Sources: AU-NEPAD, 2019 and UIS, 2018. **Researchers by formal qualification:** Adapted from OECD (2015), Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development (appendix 6.1).**Headcount (HC) of R&D personnel:** OECD (2015), Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development.

6.2.2 R&D personnel and researchers' for selected countries

The size of Tanzanian R&D personnel is far behind that of Kenya in spite of the two countries having more or less the same economic outlook and science historical background before and after independence, as shown in Table 6.5 below. The number of R&D personnel in Tanzania was 6502 in 2013, while Kenya had 61964 R&D personnel in 2010, which is more than 9 times that of the Tanzanian R&D workforce. Additionally, in 2013 the South African R&D human resource base was almost 10 times the Tanzanian R&D size in terms of personnel. The results simply show that the share of Tanzanian researcher headcounts was the lowest among the countries mentioned above in this paragraph. In this knowledge-based society, it is crucial for governments to ensure the availability of enough researchers for knowledge production, innovation, and utilisation for the socio-economic well-being of societies.

Furthermore, the AU-NEPAD (2019) and UIS (2018) reports showed that the number of researchers per million inhabitants is small compared with several sub-Saharan African partner states. The results showed that Tanzania had 73 researchers per million inhabitants, while South Africa had 859 researchers per million inhabitants, which is fourteen times the Tanzanian number. Table 6.1 shows that the Tanzanian science system has fewer researchers for its population relative to several countries in Africa as explained above. It was also noted that the number of Tanzanian researchers over the national population slightly increased from 68 researchers in 2010 to 73 researchers per million inhabitants in 2013 (AU-NEPAD, 2019;UIS, 2018).

Table 6.5: R&D personnel and researchers HC for selected countries, 2013 or latest year available

Countries	Researchers per million inhabitants	R&D personnel	Researchers	Researchers as % of R&D personnel	R&D personnel per million inhabitants
South Africa (2013)	859	68,838	45,935	67	1,289
Botswana (2013)	349	1,716	760	44	788
Namibia (2010)	341	949	748	79	433
Kenya (2010)	323	61,964	13,012	21	1,537
Malawi (2010)	125	3,809	1,843	48	258
Madagascar (2011)	109	3,088	2,364	77	142
Ethiopia (2013)	87	18,438	8,221	45	195
Uganda (2010)	85	4,270	2,823	66	129
Tanzania (2013)	73	6,502	3400	52	141
Angola (2011)	68	2,395	1,482	71	109

Data Source: AU-NEPAD, 2019 and UIS, 2018 and World Bank, 2018

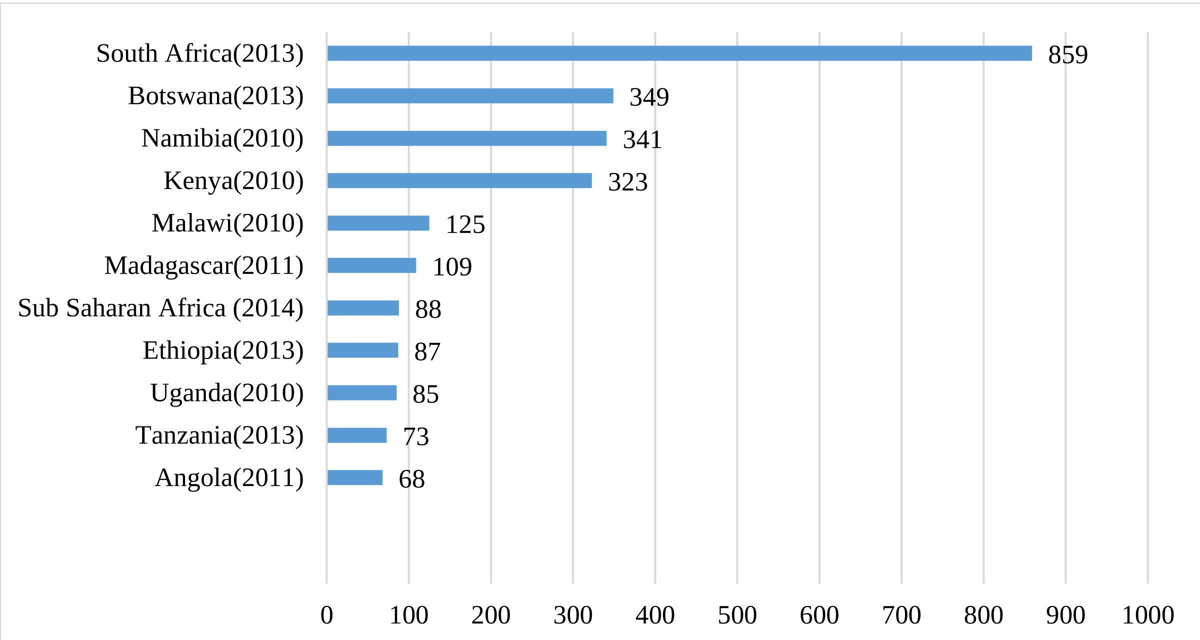

Figure 6.1: Researchers per million inhabitants for selected countries, 2014 or latest year available

Source: AU-NEPAD, 2019 and UIS, 2018

Expressed as full-time equivalents (FTE), the data shows that Tanzania had about 44.7 researchers per million inhabitants in 2013. It was noted that the number of Tanzanian researchers' FTEs per its population is behind several sub-Saharan countries (Figure 6.2). The results show that in 2010 Uganda's researchers' FTEs were about two times that of Tanzanian researchers' FTEs per million inhabitants in 2013. Furthermore, the data also showed that in 2010 the size of Kenyan researchers' FTE per one million inhabitants was about 5 times the Tanzanian capacity. When compared with South Africa, the number of Tanzanian researchers' FTEs per million inhabitants was more than 10 times that of its capacity in 2013. The data reveal the small number of the Tanzanian researchers devoted to R&D activities across the national population.

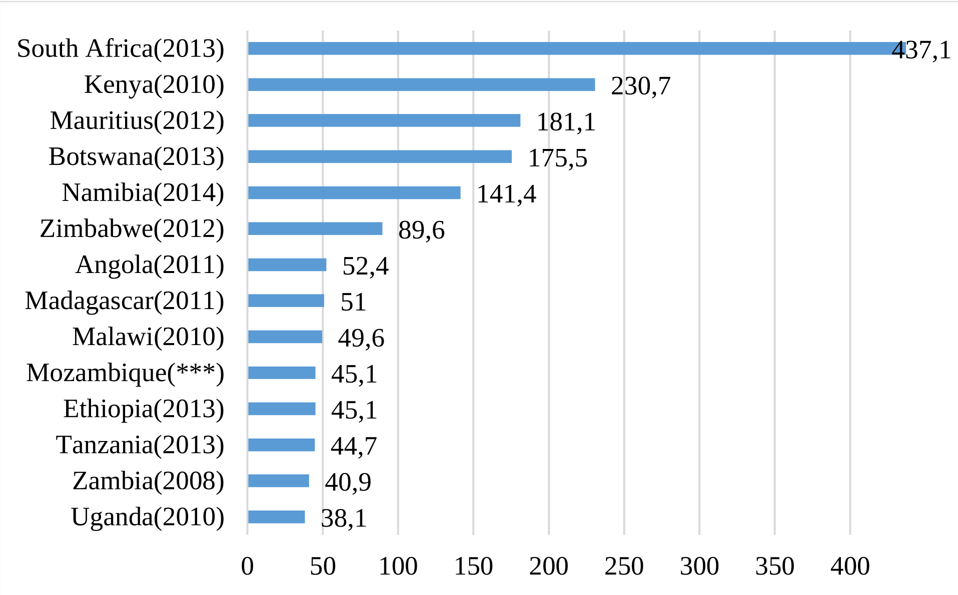

Figure 6.2: Researchers per population of 1 million inhabitants (in FTE) for selected countries, 2013 or latest year available.

*** Year not indicated

Data source: (AU-NEPAD, 2019; UIS, 2018)

6.2.3 Breakdown of researchers for selected countries by sector of employment (FTE), 2015 or latest year available

The UIS only contains information on the breakdown of Tanzanian researchers in higher education and research institutions. No data is available for the business and private non-profit research organisations for Tanzania. However, there arevery few private non-profit research organisations including the Ifakara Health Institute, Tanzania Coffee Research Institute, Tea Research Institute of Tanzania, Research for Poverty Alleviation and Economic and Social Research Foundation as shown in Chapter 4.

Expressed in FTEs, researchers in Tanzanian universities constitute the majority (71%) of all researchers, compared to the proportion of researchers in the government research institutions (29%) as indicated in Figure 6.3 below. Figure 6.3 also shows that Uganda had about 51% of researchers in the business sector, followed by South Africa (19%), Kenya (11%), Morocco (8%), Egypt (5%), Tunisia (4%), and Botswana (1%). Experience from developed countries shows the important contribution from the business sector to R&D activities and programmes. Therefore, it is high time for Tanzania to encourage and facilitate the establishment of spin-off companies under R&D which could increase technology transfer and commercialisation of research outputs.

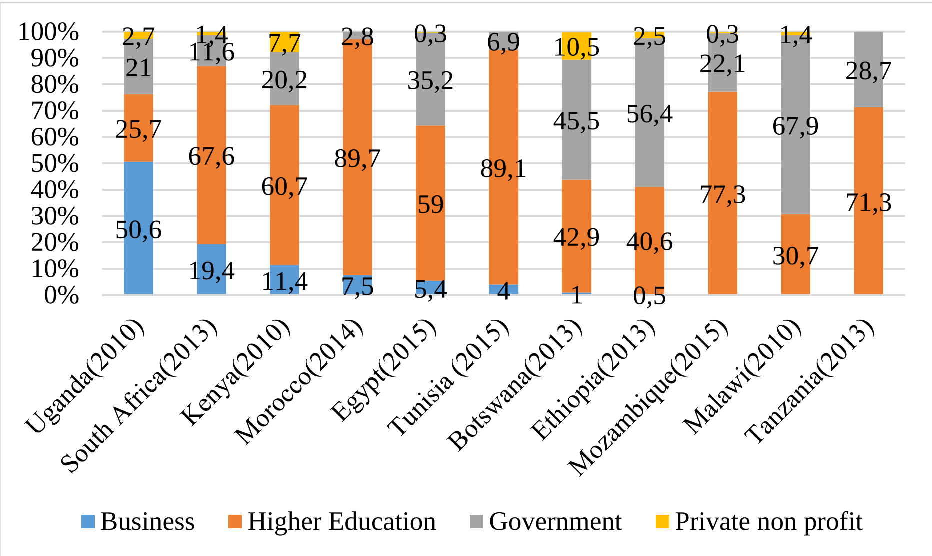

Figure 6.3: Breakdown of researchers for selected countries by sector of employment (FTE), 2015 or latest year available.

Data Source: UIS, 2018

6.2.4 The gender gap in science

In 2013, the proportion of female R&D personnel in the Tanzania science system was about 46% which is higher than several other sub Saharan African countries including Botswana (36%), Madagascar (36%), Kenya (41%) and South Africa (44%), as shown in Figure 6.4 below.

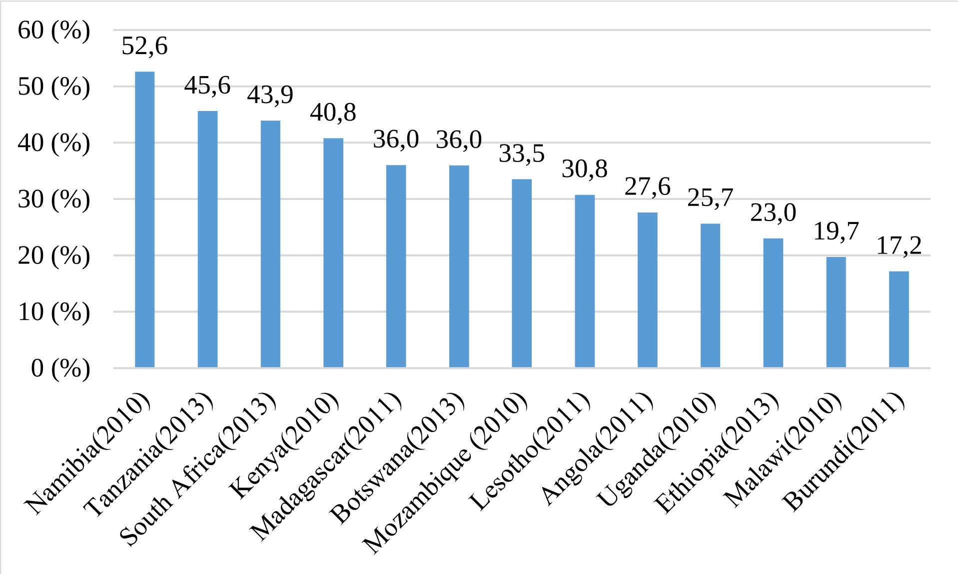

Figure 6.4: Proportion of female R&D personnel for selected countries, 2013 or latest year available.

Source: AU-NEPAD, 2019 and UIS, 2018

The results also depict that, the proportion of female R&D personnel in Tanzania between 2007 and 2013 increased from 43% to 46% while the counterparts in South Africa increased from 41% to 44% during the same period. It is noteworthy that there was a sharp decrease in the female R&D labor force in Tanzania from 43% in 2007 to 35% in 2010 as Figure 6.5 displays below. However, this cannot sufficiently be explained based on the available data and hence requires more research.

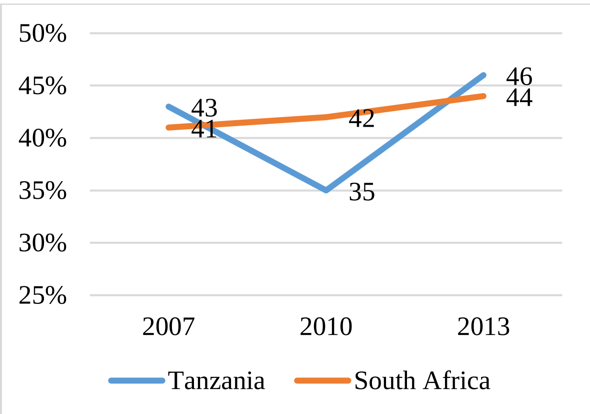

Figure 6.5: Proportion of female R&D personnel of Tanzania and South Africa

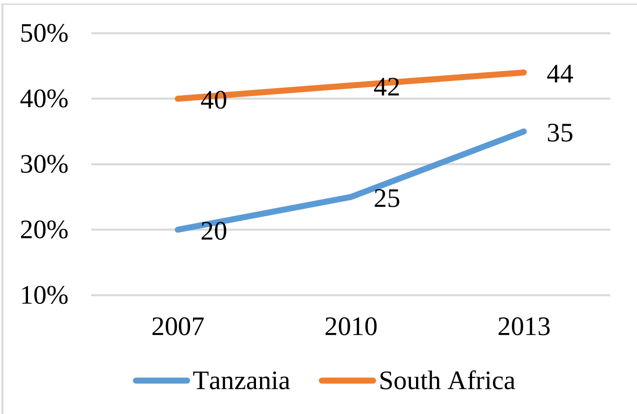

Figure 6.6: Proportion of female researchers of Tanzania and South Africa

Source: UIS, 2018

Researchers are the category of R&D workforce who are directly involved in the generation of knowledge. Therefore, measuring the number of researchers depicts the capacity of the science base whether at institutional or national level. Generally, there is a gap in the numbers of male and female researchers in R&D settings whether at regional or global levels. Based on available data for 2013, according to UIS (2015:2), the proportion of female researchers at the global level was 28.4%. From the same fact sheet, it was also noted that the proportion of female researchers in Sub Saharan Africa was 30% for the same period.

Figure 6.6 above shows that, the share of female researchers in Tanzania was 20% in 2007 and increased to 35% in 2013. As Figure 6.7 below depicts, the share of female researchers in Tanzania was 35%, which is above the world share and the regional average (for sub Saharan Africa). However, the share of Tanzanian female researchers was the lowest when compared to the female researchers in South Africa (44%), Namibia (44%), Egypt (43%) and Mauritius (42%).The data also illustrates that the proportion of female researchers in Tanzania was the highest among the East African member states of Kenya (26%), Uganda (24%) and Burundi (15%).

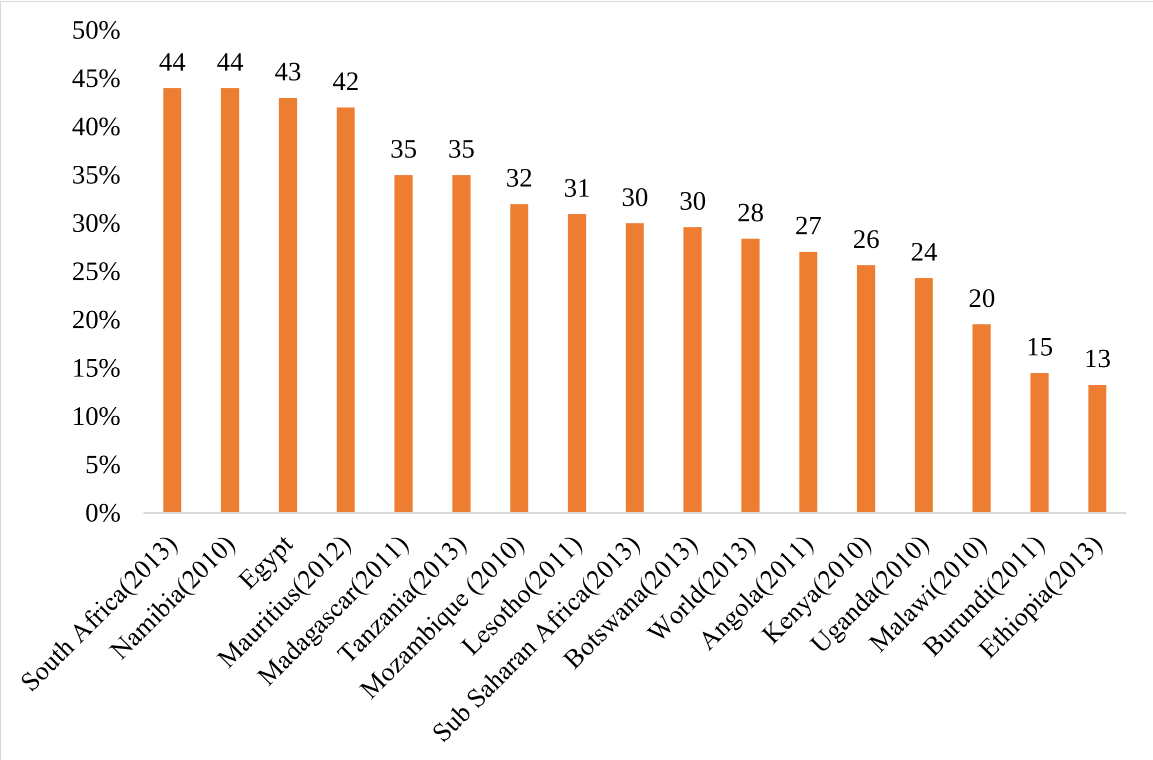

Figure 6.7: Proportion of female researchers for selected countries, 2013 or latest year available

Source: AU-NEPAD, 2014, AU-NEPAD, 2019 and UIS, 2018

Gender inequality in the social-economic and development spheres is a common phenomenon in many parts of the world. The gender inequality phenomenon, in most cases and traditions, does affect women as the marginalised and underprivileged group in the societies. Intellectually, males and females are equal. However, surrounding circumstances, traditions and culture often favour the males.

The results from internationally benchmarked assessments show that 15-year old girls outperform boys of the same age on total test averages in reading in most countries and economies (World Bank, 2018:75). The results further depict that gender-based differences in learning depend on subject. In some countries boys outperform girls in mathematics and science.

The study conducted during 2005–2013 reveals that there was an equitable enrolment ratio of boys (50.4) and girls (49.6%) in primary schools in Tanzania as a result of the primary education development programme (UNESCO, 2014:83). Generally, the enrolment of female students at universities in the country slightly increased after the government initiatives to encourage the participation of female students in higher education. The case study done at the University of Dar es Salaam shows that the ratio of female students registered for the various undergraduate programmes in 2012/2013 increased to 35% after several intervention programmes for the female students. The study reveals that the share of female students at the University of Dar es Salaam remained below 30% for many years before the intervention programmes (Kilango et. al, 2017:25). It is noted that the males leave behind the females as the education level go higher, which in turn results in the smaller share of women in R&D institutions. Special interventions and programmes should be strengthened to ensure equity in the higher education enrolment.

6.3 The main factors influencing the performance of scientists

As explained in Chapter 5, one of the objectives of the study was to find out the factors that negatively influence the research performance of scientists in in the country. The lack of mentoring and support was identified as the third largest challenge which influence the performance of scientists. Challenges related to human capacity building and professional development (lack of training opportunities to develop professional skills, and lack of mobility opportunities) were subsequently listed as the next largest challenges by scientists in the country. Balancing work and family demands was also ranked as important in influencing the performance of all respondents. Political and social factors (political instability and lack of academic freedom) received the lowest rating among the ten factors.

6.3.1 Lack of mentoring and support

Of the 142 scientists who responded to the survey questionnaire, 110 (77.5%) responded to the question, "Has the lack of mentoring and support impacted negatively on your career as an academic or scientist?" About 80% of the young scientists mentioned that the lack of mentoring and support had a negative impact on their careers (see Table 6.6, Figures 6.8 and 6.9).

- 79.5% of respondents in the 40 years or younger category indicated that at least to some extent the lack of mentoring and support has impacted negatively on their careers as academics or scientists.

- 59.2% of respondents in the 41 years or older category indicated that at least to some extent the lack of mentoring and support has impacted negatively on their careers as academics or scientists.
- 66.4% of all respondents, regardless of age group, indicated that at least to some extent the lack of mentoring and support has impacted negatively on their careers as academics or scientists.
- 42.5% of respondents who indicated that at least to some extent the lack of mentoring and support has impacted negatively on their careers, were in the 40 years or younger category.
- 57.5% of respondents who indicated at least to some extent the lack of mentoring and support has impacted negatively on their careers, were in the 41 years or older category.
- Disaggregation of the lack of mentoring and support by the two age categories of respondents indicated significant differences.

Table 6.6: Lack of mentoring and support by age groups

			Lack of mentoring and support		**Total**
			Not at all	**At least to some extent**	
Age category	**40 or younger**	Count	8	31	39
		Expected count	13.1	25.9	39.0
		% within age category	20.5%	79.5%	100.0%
		% within lack of mentoring and support	21.6%	42.5%	35.5%
		% of total	7.3%	28.2%	35.5%
	41 or older	Count	29	42	71
		Expected count	23.9	47.1	71.0
		% within age category	40.8%	59.2%	100.0%
		% within lack of mentoring and support	78.4%	57.5%	64.5%
		% of total	26.4%	38.2%	64.5%
Total		Count	37	73	110
		Expected count	37.0	73.0	110.0
		% within age category	33.6%	66.4%	100.0%
		% within lack of mentoring and support	100.0%	100.0%	100.0%
		% of total	33.6%	66.4%	100.0%

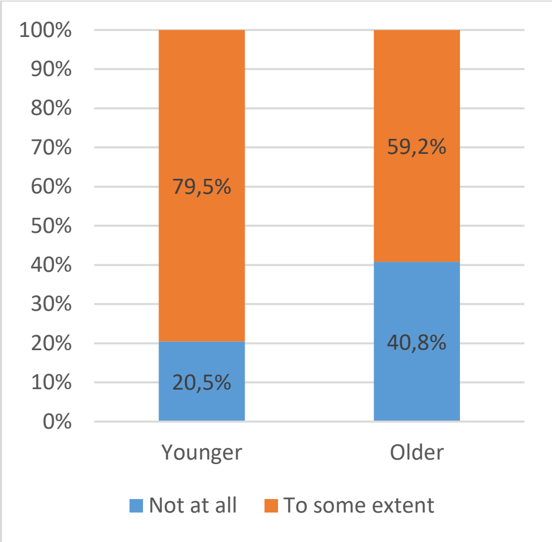

Figure 6.8 Lack of mentoring and support by age groups

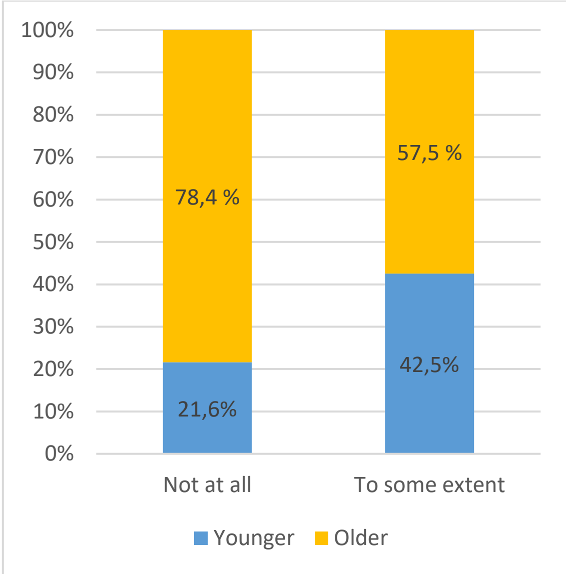

Figure 6.9: Lack of mentoring and support in combined age groups

6.3.2 Lack of training opportunities to develop professional skills

The results show that more than two thirds of all respondents, regardless of the age groups, said that the lack of training opportunities to develop professional skills had a negative impact on their careers (see Table 6.7, Figures 6.10 and 6.11).

- 68.4% of respondents in the 40 years or younger category indicated that at least to some extent the lack of training opportunities to develop professional skills has impacted negatively on their careers as academics or scientists.
- 67.1% of respondents in the 41 years or older category indicated that at least to some extent the lack of training opportunities to develop professional skills has impacted negatively on their careers as an academics or scientists.
- 67.6% of all respondents, regardless of the age group, indicated that at least to some extent the lack of training opportunities to develop professional skills has impacted negatively on their careers as academics or scientists.
- 34.7% of respondents who indicated that at least to some extent the lack of training opportunities to develop professional skills were in the 40 years or younger category.
- 65.3% of respondents who indicated at least to some extent the lack of training opportunities to develop professional skills were in the 41 years or older category.
- Disaggregation of the lack of training opportunities to develop professional skills by the two age categories of respondents, showed no significant differences.

Table 6. 7: Lack of training opportunities to develop professional skills by age groups (n = 111)

			Lack of training opportunities to develop professional skills		Total
			Not at all	At least to some extent	
Age category	40 or younger	Count	12	26	38
		Expected count	12.3	25.7	38.0
		% within age category	31.6%	68.4%	100.0%
		% within lack of training opportunities to develop professional skills	33.3%	34.7%	34.2%
		% of total	10.8%	23.4%	34.2%
	41 or older	Count	24	49	73
		Expected count	23.7	49.3	73.0
		% within age category	32.9%	67.1%	100.0%
		% within lack of training opportunities to develop professional skills	66.7%	65.3%	65.8%
		% of Total	21.6%	44.1%	65.8%
Total		Count	36	75	111
		Expected count	36.0	75.0	111.0
		% within age category	32.4%	67.6%	100.0%
		% within lack of training opportunities to develop professional skills	100.0%	100.0%	100.0%
		% of total	32.4%	67.6%	100.0%

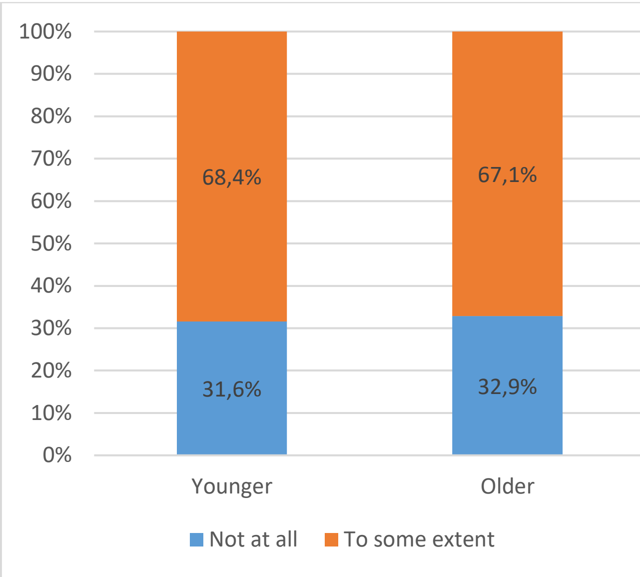

Figure 6.10 Lack of training opportunities by age groups

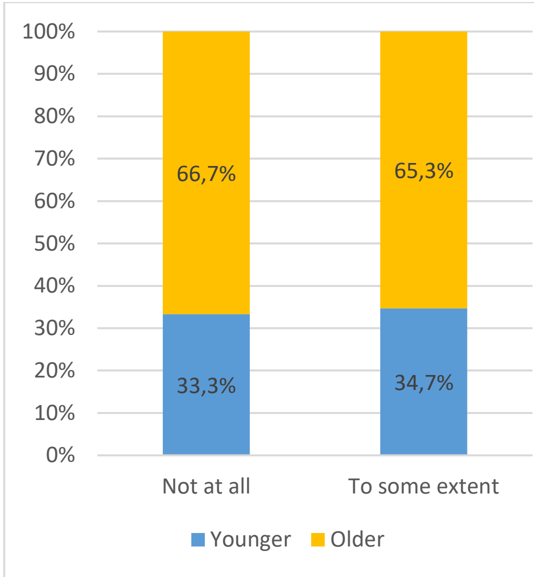

Figure 6.11: Lack of training opportunities in combined age groups

6.3.3 Lack of mobility opportunities

More than two thirds of respondents indicated that the lack of mobility opportunities had a negative impact on career development for almost two thirds of the young scientists (see Table 6.8, Figures 6.12 and 6.13).

- 64.1% of respondents in the 40 years or younger category indicated that at least to some extent the lack of mobility opportunities has impacted negatively on their careers as academics or scientists.
- 54.1% of respondents in the 41 years or older category indicated that at least to some extent the lack of mobility opportunities has impacted negatively on their careers as academics or scientists.
- 57.5% of all respondents, regardless of the two age groups, indicated that at least to some extent, the lack of mobility opportunities has impacted negatively on their careers as academics or scientists.
- 38.5% of respondents who indicated that at least to some extent the lack of mobility opportunities has impacted negatively on their careers, were in the 40 years or younger category.
- 61.5% of respondents who indicated at least to some extent the lack of mobility opportunities has impacted negatively on their careers, were in the 41 years or older category.
- Disaggregation of the lack of mobility opportunities by the two age group categories of respondents indicated no significant differences.

Table 6.8: Lack of mobility opportunities cross tabulation by age group (n=113)

			Lack of mobility opportunities		Total
			Not at all	**At least to some extent**	
Age category	**40 or younger**	Count	14	25	39
		Expected count	16.6	22.4	39.0
		% within age category	35.9%	64.1%	100.0%
		% within lack of mobility opportunities	29.2%	38.5%	34.5%
		% of total	12.4%	22.1%	34.5%
	41 or older	Count	34	40	74
		Expected count	31.4	42.6	74.0
		% within age category	45.9%	54.1%	100.0%
		% within lack of mobility opportunities	70.8%	61.5%	65.5%
		% of total	30.1%	35.4%	65.5%
	Total	Count	48	65	113
		Expected count	48.0	65.0	113.0
		% within age category	42.5%	57.5%	100.0%
		% within lack of mobility opportunities	100.0%	100.0%	100.0%
		% of total	42.5%	57.5%	100.0%

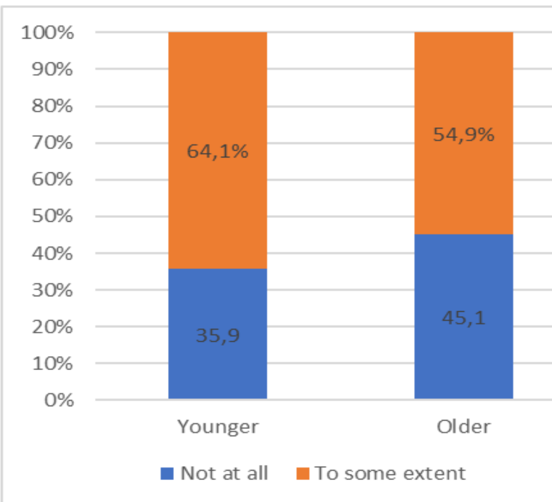

Figure 6.12 Lack of mobility opportunities by age groups

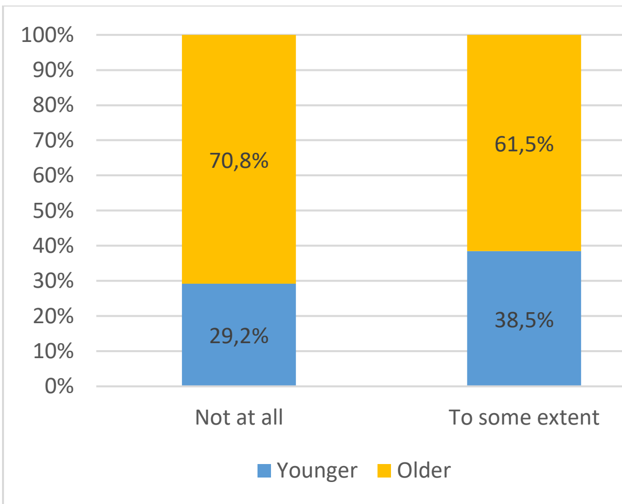

Figure 6.13: Lack of mobility opportunities in combined age groups

6.3.4 Balancing work and family demands

One hundred and nine individuals responded to the question, "Has balancing work and family demands impacted negatively on your career as an academic or scientist?" Balancing work and family demands had a negative impact on career development for almost 58% of the young scientists. The results also indicated that balancing work and family demands is more an issue of concern for the 41 years or older group, in which 68% of the group had a negative impact in their careers (see Table 6.9, Figures 6.14 and 6.15).

- 57.9% of respondents in the 40 years or younger category indicated that, at least to some extent, balancing work and family demands, has impacted negatively on their careers as academics or scientists.
- 69.0% of respondents in the 41 years or older category indicated that, at least to some extent, balancing work and family demands, has impacted negatively on their careers as academics or scientists.
- 65.1% of all respondents, regardless of the two age groups, said that at least to some extent, balancing work and family demands, has impacted negatively on their careers as academics or scientists.
- 31.0% of respondents who indicated that at least to some extent, balancing work and family demands has impacted negatively on their careers**,** were in the 40 years or younger category.
- 69.0% of respondents who indicated that at least to some extent balancing work and family demands has impacted negatively on their careers, were in the 41 years or older category.
- Disaggregation of balancing work and family demands by the two age groups of respondents indicated no significant differences. In both age groups to some extent balancing work and family demand has impacted negatively on their careers.

Table 6.9: Balancing work and family demands by age group

			Balancing work and family demands		**Total**
			Not at all	**At least to some extent**	
Age category	**40 or younger**	Count	16	22	38
		Expected count	13.2	24.8	38.0
		% within age category	42.1%	57.9%	100.0%
		% within balancing work and family demands	42.1%	31.0%	34.9%
		% of total	14.7%	20.2%	34.9%
	41 or older	Count	22	49	71
		Expected count	24.8	46.2	71.0
		% within age category	31.0%	69.0%	100.0%
		% within balancing work and family demands	57.9%	69.0%	65.1%
		% of total	20.2%	45.0%	65.1%
		Count	38	71	109

Total	Expected count	38.0	71.0	109.0
	% within age category	34.9%	65.1%	100.0%
	% within balancing work and family demands	100.0%	100.0%	100.0%
	% of total	34.9%	65.1%	100.0%

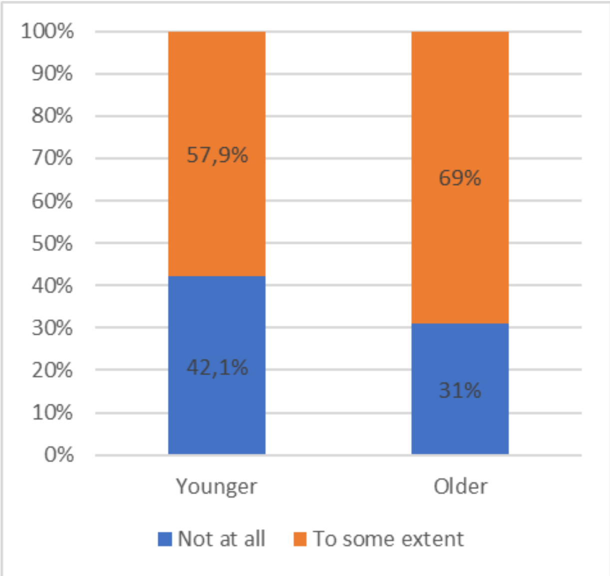

Figure 6.14: Balancing work and family demands by age groups

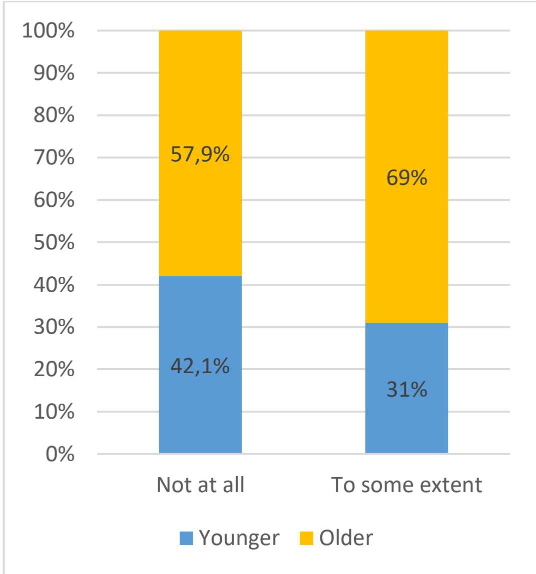

Figure 6.15: Balancing work and family demands in combined age groups

6.3.5 Lack of access to library and/or information sources

Lack of access to library and/or information sources had a negative impact on career development for about 42% of the young scientists (see Table 6.10 , Figures 6.16 and 6.17).

- 42.1% of respondents in the 40 years or younger category indicated that at least to some extent the lack of access to library and/or information sources has impacted negatively on their careers as academics or scientists.
- 57.5% of respondents in the 41 years or older category indicated that at least to some extent the lack of access to library and/or information sources has impacted negatively on their careers as academics or scientists.
- 52.3% of all respondents, regardless of the age groups, indicated that at least to some extent the lack of access to library and/or information sources has impacted negatively on their careers as academics or scientists.
- 27.6% of respondents who indicated that at least to some extent, the lack of access to library and/or information sources has impacted negatively on their careers, were in the 40 years or younger group.

- 72.4% of respondents who indicated that at least to some extent the lack of access to library and/or information sources has impacted negatively on their careers, were in the 41 years or older group.
- Disaggregation of the lack of access to library and/or information sources by the two age groups of respondents indicated no significant differences.

Table 6.10: Lack of access to library and/or information sources by age group

			Lack of access to library and/or information sources		Total
			Not at all	**At least to some extent**	
Age category	**40 or younger**	Count	22	16	38
		Expected count	18.1	19.9	38.0
		% within age category	57.9%	42.1%	100.0%
		% within lack of access to library and/or information sources	41.5%	27.6%	34.2%
		% of total	19.8%	14.4%	34.2%
	41 or older	Count	31	42	73
		Expected count	34.9	38.1	73.0
		% within age category	42.5%	57.5%	100.0%
		% within lack of access to library and/or information sources	58.5%	72.4%	65.8%
		% of total	27.9%	37.8%	65.8%
Total		Count	53	58	111
		Expected count	53.0	58.0	111.0
		% within age category	47.7%	52.3%	100.0%
		% within lack of access to library and/or information sources professional skills	100.0%	100.0%	100.0%
		% of total	47.7%	52.3%	100.0%

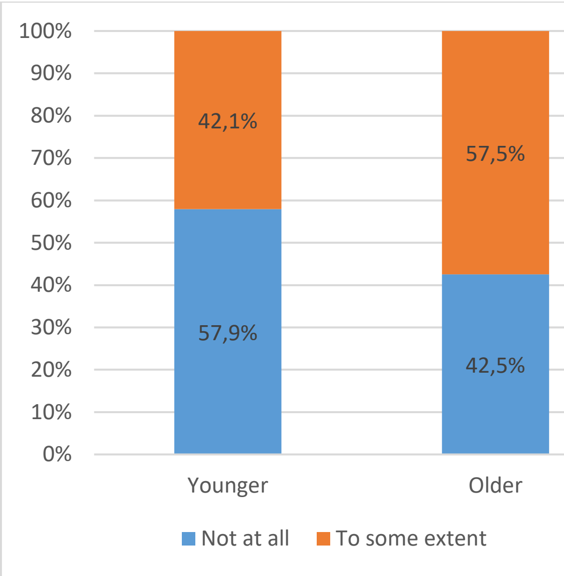

Figure 6.16: Lack of access to library by age groups

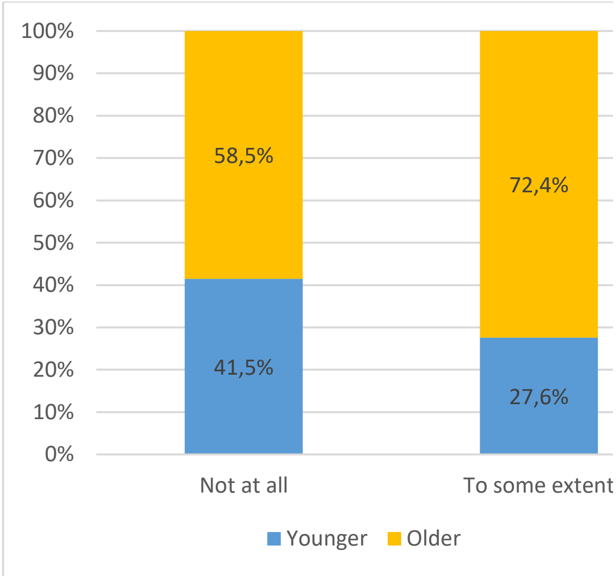

Figure 6.17: Lack of access to library in combined age groups

6.3.6 Job insecurity

One hundred and six (74.7%) responded to the question, "Has job insecurity impacted negatively on your career as an academic or scientist?" About half of the young scientists indicated that job insecurity had a negative impact on their careers (see Table 6.11, Figures 6.18 and 6.19).

- 50.0% of respondents in the 40 years or younger group indicated that job insecurity not at all has impacted negatively on their careers as academics or scientists.
- 66.2% of respondents in the 41 years or older group indicated that job insecurity not at all has impacted negatively on their careers as academics or scientists.
- 60.4% of all respondents, regardless of the two age groups, indicated that job insecurity not at all has impacted negatively on their careers as academics or scientists.
- 45.2% of respondents who indicated that at least to some extent job insecurity has impacted negatively on their careers, were in the 40 years or younger category.
- 54.8% of respondents who indicated
- that at least to some extent job insecurity has impacted negatively on their careers, were in the 41 years or older group.
- Disaggregation of job insecurity by the two age categories of respondents indicated no significant differences.

Table 6.11: Job insecurity by age group (n = 106)

			Job insecurity: Not at all	Job insecurity: At least to some extent	Total
Age category	**40 or younger**	Count	19	19	38
		Expected count	22.9	15.1	38.0
		% within age category	50.0%	50.0%	100.0%
		% within job insecurity	29.7%	45.2%	35.8%
		% of total	17.9%	17.9%	35.8%
	41 or older	Count	45	23	68
		Expected count	41.1	26.9	68.0
		% within age category	66.2%	33.8%	100.0%
		% within job insecurity	70.3%	54.8%	64.2%
		% of total	42.5%	21.7%	64.2%
Total		Count	64	42	106
		Expected count	64.0	42.0	106.0
		% within age category	60.4%	39.6%	100.0%
		% within job insecurity	100.0%	100.0%	100.0%
		% of total	60.4%	39.6%	100.0%

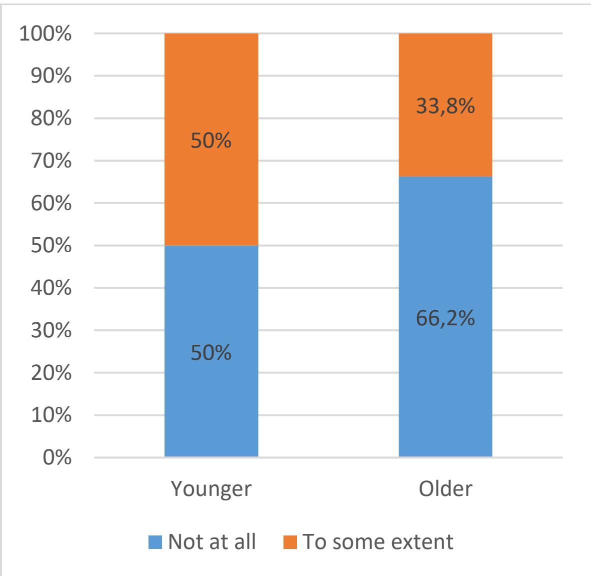

Figure 6.18: Job insecurity by age groups

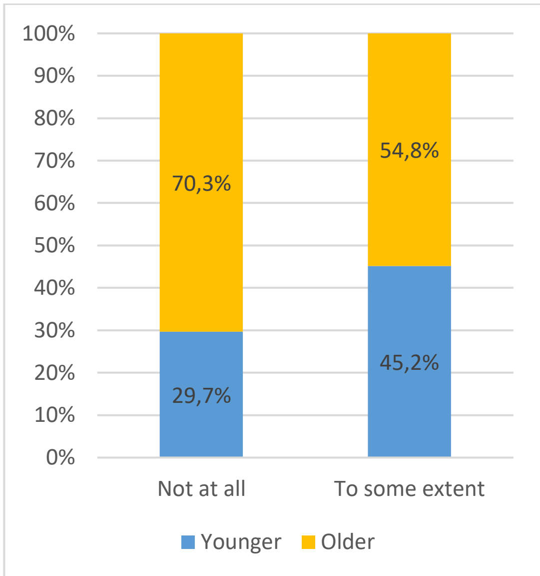

Figure 6.19: Job insecurity in combined age groups

6.3.7 Limitation of academic freedom

About 57.9% of the young scientists mentioned that the limitation of academic freedom had no negative impact on their careers at all. The results further indicated that more than two thirds of all respondents, regardless of the age groups, said that the limitation of academic freedom had no negative impact on their career development (see Table 6.12, Figures 6.20 and 6.21).

- 57.9% of respondents in the 40 years or younger group indicated that the limitation of academic freedom not at all impacted negatively on their careers as academics or scientists.
- 72.2% of respondents in the 41 years or older group indicated that limitation of academic freedom has not at all impacted negatively on their careers as academics or scientists.
- 67.3% of all respondents, regardless of the age group, indicated that the limitation of academic freedom has not at all impacted negatively on their careers as academics or scientists.
- 29.7% of respondents who indicated that the limitation of academic freedom not at all impacted negatively on their careers, were in the 40 years or younger category.
- 70.3% of respondents who indicated that the limitation of academic freedom not at all impacted negatively on their careers, were in the 41 years or older group.
- Disaggregation of limitation of academic freedom by the two age groups of respondents indicated no significant differences.

Table 6.12: Limitation of academic freedom by age group (n = 110)

			Limitation of academic freedom		Total
			Not at all	**At least to some extent**	
Age category	**40 or younger**	Count	22	16	38
		Expected count	25.6	12.4	38.0
		% within age category	57.9%	42.1%	100.0%
		% within limitation of academic freedom	29.7%	44.4%	34.5%
		% of total	20.0%	14.5%	34.5%
	41 or older	Count	52	20	72
		Expected count	48.4	23.6	72.0
		% within age category	72.2%	27.8%	100.0%
		% within limitation of academic freedom	70.3%	55.6%	65.5%
		% of total	47.3%	18.2%	65.5%
Total		Count	74	36	110
		Expected count	74.0	36.0	110.0
		% within age category	67.3%	32.7%	100.0%
		% within limitation of academic	100.0%	100.0%	100.0%
		% of total	67.3%	32.7%	100.0%

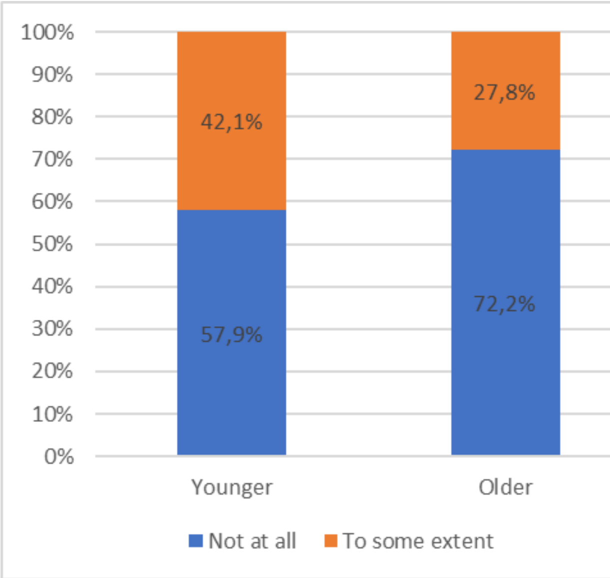

Figure 6.20: Limitation of academic freedom by age groups

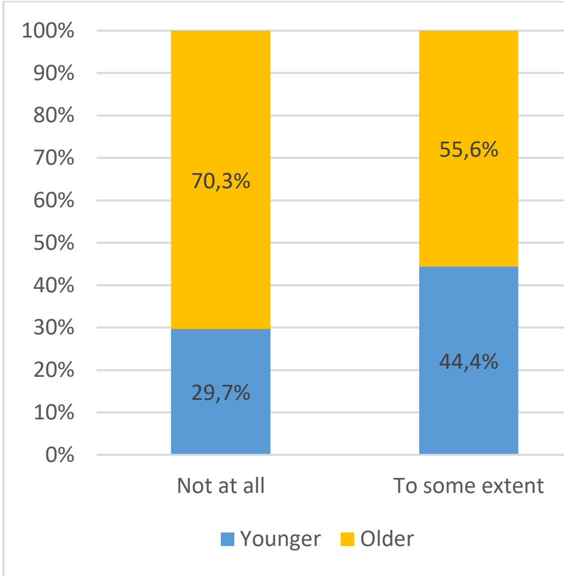

Figure 6.21: Limitation of academic freedom in combined age groups

6.3.8 Political instability

Of the 142 scientists who responded to the survey questionnaire, about 92% of the young scientists mentioned that political instability had no negative impact on their careers at all. Additionally, findings also showed that about 92% of all respondents, regardless of the age groups, indicated that political instability had no negative impact on their career development at all (see Table 6.13, Figures 6.22 and 6.23).

- 91.9% of respondents in the 40 years or younger group indicated that political instability not at all has impacted negatively on their careers as academics or scientists.
- 91.5% of respondents in the 41 years or older category indicated that political instability not at all has impacted negatively on their careers as academics or scientists.
- 91.7% of all respondents, regardless of the age group, indicated that political instability has not at all impacted negatively on their careers as academics or scientists.
- 34.3% of respondents who indicated that political instability not at all impacted negatively on their careers, were in the 40 years or younger group.
- 65.7% of respondents who indicated that political instability not at all impacted negatively on their careers, were in the 41 years or older category.
- Disaggregation of political instability by the two age groups of respondents, indicated no significant differences.

Table 6.13: Political instability by age group (n = 108)

			Political instability		Total
			Not at all	At least to some extent	
Age category	40 or younger	Count	34	3	37
		Expected count	33.9	3.1	37.0
		% within age category	91.9%	8.1%	100.0%
		% within political instability	34.3%	33.3%	34.3%
		% of total	31.5%	2.8%	34.3%
	41 or older	Count	65	6	71
		Expected count	65.1	5.9	71.0
		% within age category	91.5%	8.5%	100.0%
		% within political instability	65.7%	66.7%	65.7%
		% of total	60.2%	5.6%	65.7%
Total		Count	99	9	108
		Expected count	99.0	9.0	108.0
		% within age category	91.7%	8.3%	100.0%
		% within political instability	100.0%	100.0%	100.0%
		% of total	91.7%	8.3%	100.0%

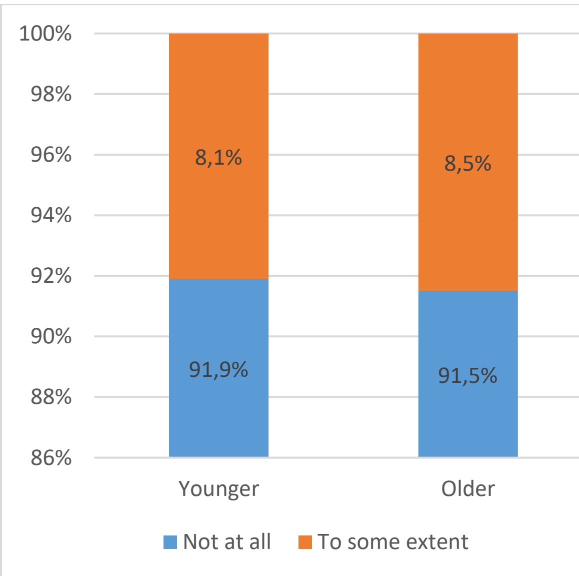

Figure 6.22: Political instability by age groups

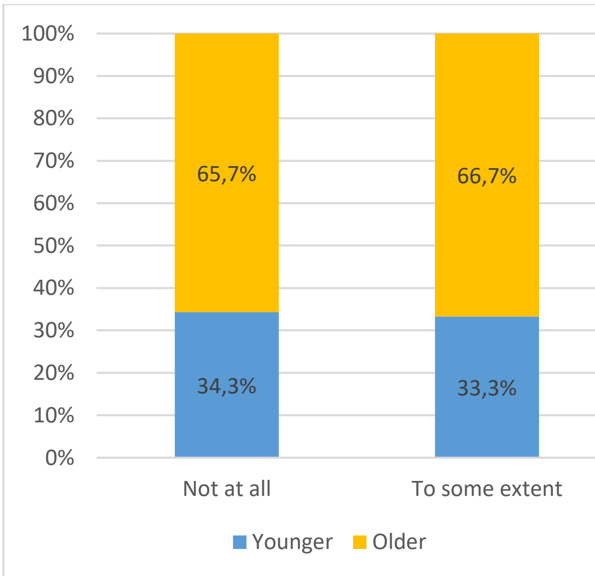

Figure 6.23: Political instability in combined age groups

6.4 Discussion

The human resources base in R&D in Tanzania is insufficient to harness the social-economic potential of the country available through the production and utilisation of knowledge, products and services. Most higher learning institutions and R&D institutions in the country experience a shortage of staff, which contributes to the low production and productivity of scientific outputs in the country. Several reports indicate a shortage of skilled human resources in the Tanzanian national system of innovation.

The most recent African Innovation Outlook III report (AU-NEPAD, 2019) indicates the growing number of personnel headcounts in R&D institutions in Tanzania from 5788 in 2010 to 6502 in 2013, which is about 12% growth (COSTECH, 2015c). The increase in the number of Tanzanian personnel headcounts in R&D institutions is still inadequate when considering the size and number of R&D institutions in the country.

The AU-NEPAD (2019) reports indicates that the Tanzania number of researchers per million inhabitants is small compared with several countries in Africa. The report indicates that Tanzania had 73 researchers per million inhabitants while Kenya had 323 researchers per million inhabitants which is more than four times of Tanzania researchers.In 2013, researchers per million inhabitants in the following countries were South Africa (859), Botswana (349), Namibia 341, Kenya 323, Malawi 125, Madagascar 109, Ethiopia (87), and Uganda (85). Expressed in full-time equivalents (FTE), the UNESCO data indicate that Tanzania had about 44.7 researchers per million inhabitants in 2013 (AU-NEPAD, 2019) which is behind several Sub Saharan countries. For instance, the data show that in 2010 Kenya's researchers FTEs was 230.7 researchers per million inhabitants, which is about five folds of Tanzania's counterparts. Additionally, South Africa had 437.1 FTEs per million inhabitants in 2013 which is about 10 times of Tanzania counterparts.

The proportion of female researchers in Tanzania gradually increased from 20% in 2007 to about 35% in 2013 (UIS, 2018). Nevertheless, the proportion of Tanzania female researchers is still relatively low when benchmarked with the South Africa female researchers (44%) and Namibia (44%). There is still a big leakage of the female students from the lower school levels to the university level. The government needs to device more mechanisms to increase the number of the females to participate in science programs from the lower levels to the tertiary level.

In the survey findings, the lack of mentoring and support was identified as the third largest challenge which influences the performance of young scientists.The survey findings indicated that about 80% of the young scientists mentioned that the lack of mentoring and support had a negative impact on their careers. The lack of mentorship programmes is an issue of concern for the career development of young scientists in the country. The earlier study by Gaillard, et al., (2002:52) also indicated that senior scientists are overworked with teaching load and administration duties and have very little time for conducting research. Young scientists in the early career stages need to be under a mentorship programme by senior scientists to build their future careers. As Beaudry, Mouton and Prozesky (2018:102) notes, young scientists expressed a necessity for clarity from senior scientists on the requirements needed in undertaking an effective research career. These embrace an understanding of university cultures, procedures, lecturing duties and scientific publications. However, in most cases there is a lack of mentorship from senior scientists as mentors and role models.

Additionally the majority of the Tanzanian government staff profile, including the academic staff profile, is aging simply because of the cessation of government employment between the 1990s and 2000s. The employment gap resulted in a work overload in most of the R&D institutions. One of the interviewees noted that:

> [M]entorship is also not adequate in our places because people, you find that they are busy. Maybe you have some senior staff, the university staff, but they are quite busy with other issues or they are quite busy with other students. So mentorship to young academics, stuff like that, may be is not adequate.

Opportunities for scientists to go abroad and engage with other scholars is important in the career development and to take advantage of networking, get access to research funding, and to modern laboratory equipment (Beaudry, Mouton and Prozesky, 2018:103). In the survey results, challenges related to human capacity building and professional development (lack of training opportunities to develop professional skills and the lack of mobility opportunities) were subsequently listed as the two next largest challenges for the young scientists in the country. Balancing work and family demands was also ranked as important in influencing the performance of all respondents. Political and social factors (political instability and lack of academic freedom) received the lowest rating, which was not a surprising result, since the country has been politically stable for several decades and R&D institutions are semi-autonomous.

The lack of mobility also was mentioned by the interviewees to be one of the important factors which negatively influence the performance of young scientists. Furthermore, the shortage of postdoctoral research opportunities in Tanzania is one of the issues that affect the performance of young researchers in the country. There are very few R&D institutions which offer post-doctoral fellowships in the country and most of the funding originate from external sources. The Tanzania Commission for Science and Technology, through Sida support, formulated the National Framework for Post-doctoral Research to encourage post-doctoral fellowships in the country (URT, 2018). Post-doctoral fellows normally are exposed to a wide range of research networks, mobility and collaboration with scholars within and outside the country. It is high time also to focus on post-doctoral research programmes in order to build research excellence in the country. Post-doctoral programmes entail building research competence for competitive research, incentivise, attract and retain skilled research staff, and is a factor that will contribute to improved research outputs and outcomes in Tanzania (URT, 2018:3).

Scientists need to be aware of the current state of knowledge, products and processes in their field. Science and technology are dynamic and moving fast, especially in the 4th industrial revolution. In this situation scientists needs to be updated and equipped with emerging knowledge and technologies. One of the young scientists during the interview noted that:

> [I]f we had these short courses also, they could equip us, update information with regards to the particular research, and also give us some insights on how to write a good proposal that can….. Yes, so I think it would be more important and it could help us to get that kind of research funds.
>
> The scientist also indicates that he is ready to leave the country to pursue a post-doctoral research whenever opportunity arise.
>
> If I have an opportunity, I would wish to go abroad because I feel like since my PhD …, when I was doing it in Japan, now from then, I have never gone out of the country for any short training. So if I get … research, I think I would be willing to go anytime.

Generally, balancing work and family demands was ranked number five among the ten factors which negatively influence the research performance of scientists. The survey analysis indicated that balancing work and family demands is more an issue of concern for the senior scientists (3rd ranked), whereby 70% of senior scientists indicated that it had a negative impact on their career development. This probably could be explained by relatively increased work and family demands (teaching, administrative duties and family matters) for the senior scientists. On the other hand, about 58% of the young scientists showed that balancing work and family demands had a negative impact on their career development. In totality, about two thirds of all respondents, irrespective of the age group, said that balancing work and family demands had a negative effect on their career development as scientists.

The proportion of 42% of young scientist indicated that the lack of access to library and information resources by age group had a negative impact on career development. The fact that lack of access to library and information resources was rated relatively low when compared with other factors, may be an indication that many scientists nowadays have access to the scholarly information sources through the internet, rather than relying merely on institutional libraries. However, it is a fact that many institutional and public libraries are not automated and contain old books and few current scholarly materials. For instance, the University of Dar es Salaam, which is the oldest and largest university in the country, in 2018 started to run a new library which was financed by the Chinese government. However, the library is still lacking new books and other literary materials for learning and research activities. The access to libraries and information or resources is a barrier to academic career development for the young scientists in the country, as one of the interviewees noted:

> Here in Tanzania, for example, our university is not subscribed to most of the important journals worldwide that you can get some concrete information regarding the particular research you are doing. So that is one factor which is really setting us back from doing more research. Also, our libraries here are also not fully equipped with the books. So we rely on the limited resources through the internet, but also, you don't get much.

The survey findings show that about 60.4% of all respondents, regardless of the age group, said that job insecurity has not been a challenge for their career development as scientists. Also, results further indicated that for more than two thirds of all respondents, irrespective of the age group, the limitation of academic freedom had no negative impact on their career development. Again, for about 92% of all respondents, regardless of the age group, political instability had not influenced their careers negatively . It was not surprising that political and social factors (job insecurity, political instability and lack of academic freedom) received the lowest ratings. This could be probably due to the social and political stability of the country for several decades, coupled with permanent and pensionable positions for respondents working in the government R&D institutions, which comprised the majority of respondents in the survey.

CHAPTER 7: RESEARCH PERFORMANCE: PUBLICATIONS AND CITATION IMPACT

7.1 Introduction

Bibliometrics refers to the application of quantitative methods to books, texts and other communication media (Pritchard, 1969:349). Bibliometrics is a tool by which the state of science and technology (S&T) in a country, institutions or department can be measured in terms of scientific production, productivity, citation visibility and collaboration trends (Okubo, 1997).

The bibliometric analyses of the science system in Tanzania intend to provide empirical informed evidence to stimulate policy and institutional changes to improve the Tanzanian research performance and the entire science, technology and innovation (STI) system for the social-economic development of the country. This bibliometric analysis in this Chapter focuses on an assessment of the research performance of R&D institutions in Tanzania, scientific publication trends, and the impact of produced scientific knowledge. In measuring the state and performance of the Tanzanian science system, several bibliometric indicators were analysed, including scientific research outputs, percentage of the world share, relative field strength (RFS), the mean normalised field citation score (MNCS), positional analysis, collaboration rate, and other related indicators.

The presentation and results of bibliometric indicators have been grouped into themes and sub-themes based on the research questions of the study to ensure cohesion across the whole study as described in the methodology chapter. Table 7.1 below shows specific research questions, which have been analysed, and findings presented and discussed in this Chapter.

Table 7.1: Conceptual framework outlining the main themes and sub-themes for the presentation and results of bibliometric indicators.

<table>
<tr><th>Main themes</th><th>Sub-themes</th><th>Research questions</th><th>Applied tools</th></tr>
<tr><td rowspan="2">Research performance: Publications and citation impact</td><td>Trends and distribution across the scientific fields</td><td>• What are the main trends of scientific publications between 2005 and 2018?
• What is the sector-wide distribution of publication outputs?</td><td rowspan="2">Bibliometrics</td></tr>
<tr><td>Top performing R&D institutions</td><td>• Which are the top R&D institutions in terms of publication outputs?</td></tr>
</table>

Main themes	Sub-themes	Research questions	Applied tools
	Impact, relative field strengths and positional analysis across scientific fields	• What is the Tanzanian relative field strength of scientific domain outputs globally? • What are the trends in the citation impact of Tanzanian science between 2005 and 2018? • Which are the high impact fields? • What is the Tanzanian positional analysis for produced scientific domains globally?	

The bibliometric data on scientific publication outputs of Tanzania were retrieved from the WoS database and covers fourteen years' period (2005–2018). The bibliometric analyses focused on articles and review articles only.

7.2 Bibliometrics indicators defined

The following bibliometric indicators were used to present a view of the state of Tanzania's publication production.

Publication outputs: As a simple indicator of scientific papers production, it provides a count of scientific papers within and across scientific fields. It can be used in measuring and comparing the production of scientific knowledge at institutions, regions or national levels.

Specialisation index (SI) synonymous with relative field strength (RFS). The indicator indicates the concentration of knowledge production in particular scientific fields, taking the world proportion as the baseline. Therefore, the SI indicator reflects the research intensity or effort of a given country, in a particular scientific field, relative to the world average in the same research field. An index value above 1 (world average) indicates that a given scientific field or sub-field is specialised relative to the world average, whereas an index value below 1 means the opposite. The RFS is calculated as follows:

$$RFS = \frac{\textit{The given field's share in the particular country (Institution) publication output}}{\textit{Field share of publication by the world}}$$

Where n_f is the number of publications produced by the entity in the field f, while n_t is the number of publications produced by an entity across all fields, N_f is the number of publications produced by the world in the field f and N_t is the total number of publications produced by the world.

Mean normalised citation score (MNCS): Subject-specific peculiarities of publication and citation behaviour differ hugely between scientific disciplines (Mouton, 2017). It is therefore not possible to compare the raw numbers of citations received by papers in different disciplines (Glänzel et al., 2009).

This is due to differences among scientific fields in the average number of cited papers per publication, the average number of years of cited papers, and the degree to which references from other fields are cited (Glänzel et al., 2009;Waltman et al., 2011:37). Therefore, it is essential that careful control is in place for the differences of the scientific fields, especially in the case of performance evaluations at higher levels of aggregation, such as at the countries or multidisciplinary research groups (Waltman et al., 2011:37). According to Van Raan (2005), in the performance evaluation of research, the Centre for Science and Technology Studies (CWTS) of Leiden University, in the Netherlands uses a standard set of bibliometric indicators that rely on a normalisation of scientific fields that aim to correct for the differences among fields. Therefore, a common indicator that corrects this issue is the MNCS, which is normalised for both the scientific disciplines associated with a publication, as well as the year of publication. For instance, a MNCS of 2 means that the papers from the country (in this scenario) have been cited twice above the world average of the fields in which they published in a specified year or citation window. According to the convention established by the Centre for Science and Technology Studies (CWTS) at the University of Leiden, an MNCS of 1 indicates that a national citation impact is corresponding with the world average in the selected fields. A MNCS between 0.8 and 1.0 is regarded as reasonably good, while an MNCS between 1.0 and 1.2 is considered good. Anything above the value of 1.2 is regarded as very good (Mouton, 2019).

Positional analysis: The analysis provides the interpretation of relative field strength and weaknesses of a given scientific field by combining three indicators in a two-dimensional space with four quadrats. The horizontal axis corresponds to the specialisation index (SI), while the vertical axis reflects the impact of a given scientific field or sub-field. The position analysis of a country or institution in a given scientific domain can therefore be interpreted as follows (see Figure 7.1):

- **Quadrant 1:** Located at the top right of the graph, this quadrant means excellence. A country in this quadrant specialises in the given scientific field and their activities have a high impact.
- **Quadrant 2:** Located at the top left of the graph, this quadrant means high-impact scientific output, but the country is not specialised in the given scientific domain.
- **Quadrant 3:** Located at the bottom right of the graph, this quadrant indicates specialisation in the scientific field, although the impact is below the world average.
- **Quadrant 4:** Located at the bottom left of the graph, this quadrant indicates that the country is not specialised in the given scientific domain and its impact is below the world average. The size of the bubble indicates the volume of scientific publications.

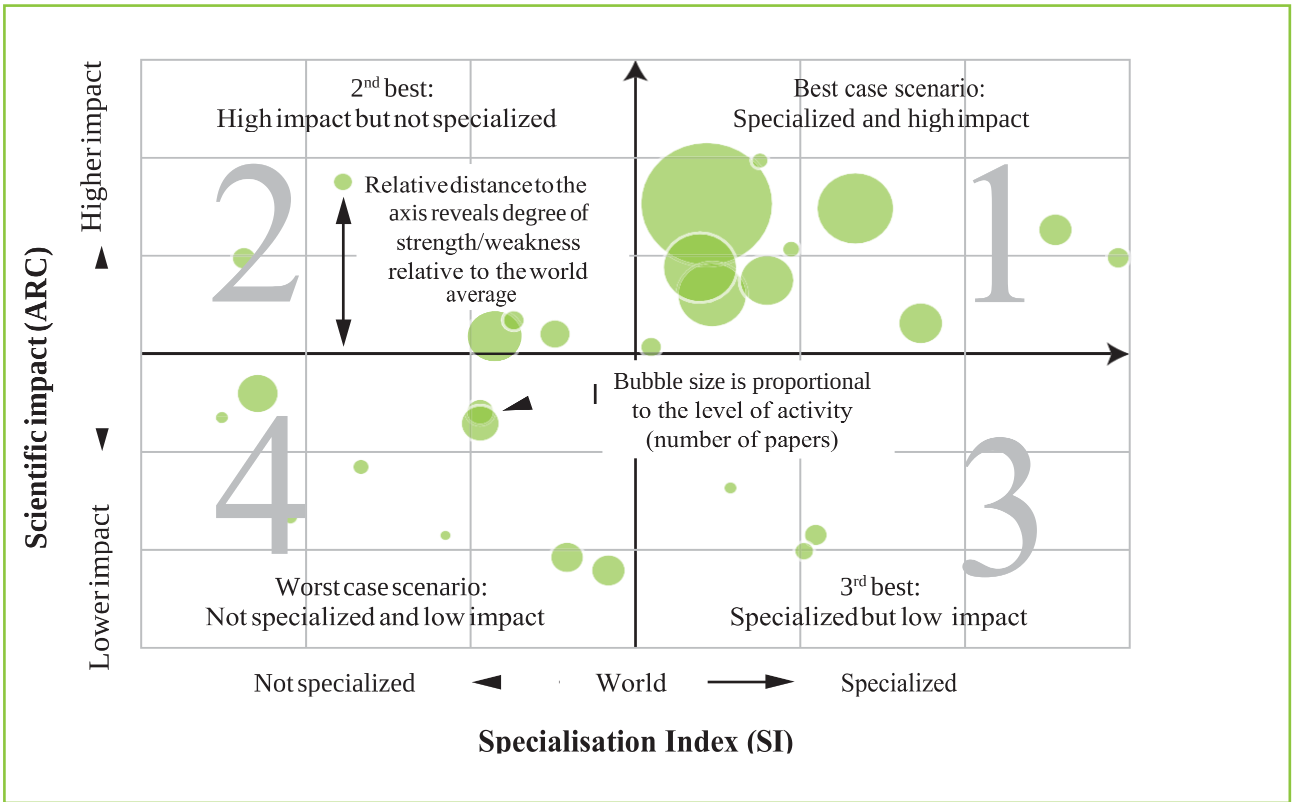

Figure 7.1: Positional analysis graph

Source: AOSTI (2014.2. Publication trends and outputs across the scientific fields

7.3 Publication output

Tanzanian publication output has been gradually increasing from 329 publications in 2005 to 1389 publications in 2018. In addition, its world share doubled from 0.036% in 2005 to 0.071% in 2018. The results also indicate that there was an average annual growth of 65.8 publications. As Figure 7.2 below indicates, between 2005 and 2012 there was a steady increase in the publication outputs from 329 papers to 710 papers followed by a sharp increase in the publication outputs from 869 to 1389 publications since then.

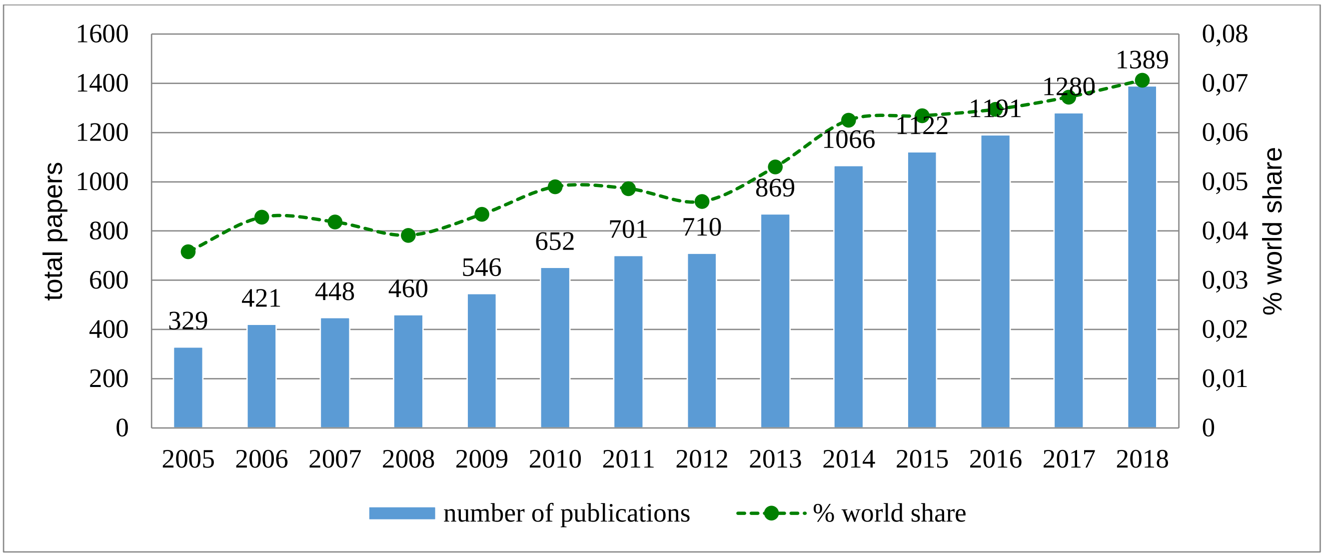

Figure 7.2: Tanzanian world share and publication outputs (articles and reviews)

Normalising publication outputs by using FTE provides a more accurate productivity indicator. Since there is no available information of Tanzania FTE researchers for all fourteen years (2005-2018), we decided to normalise the publication outputs of the country from 2005 to 2018 by the country population (million of the population) for the respective years. Figure 7.3 below displays the publication outputs per million of the population.

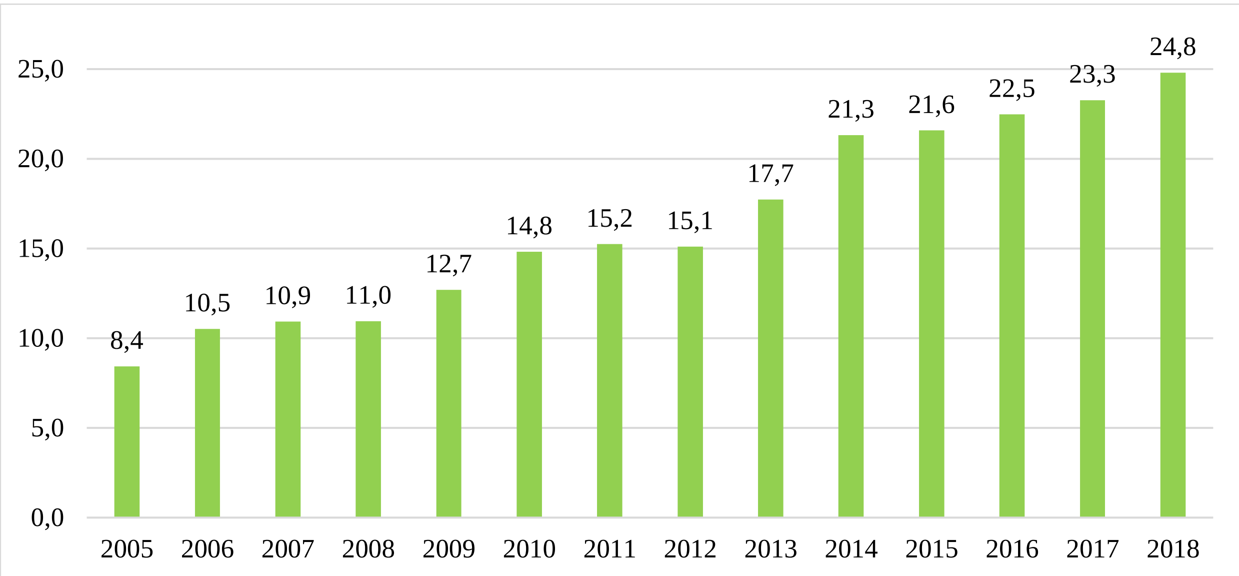

Figure 7.3: Publication outputs per million of the population from 2005–2018

Disaggregation by scientific field shows that the highest proportion of publication outputs was produced by the health sciences (44%), followed by the natural sciences (25%), social sciences (15%), and agricultural sciences (10%) (Figure 7.4). The engineering and applied technology and humanities scientific fields are the least prolific fields in publication with the proportion of about 4% and 2% respectively. The results also indicate that the share of publication outputs in the agricultural sciences declined from about 15% in 2005 to about 10% in 2018 as Figure 7.5 displays below.

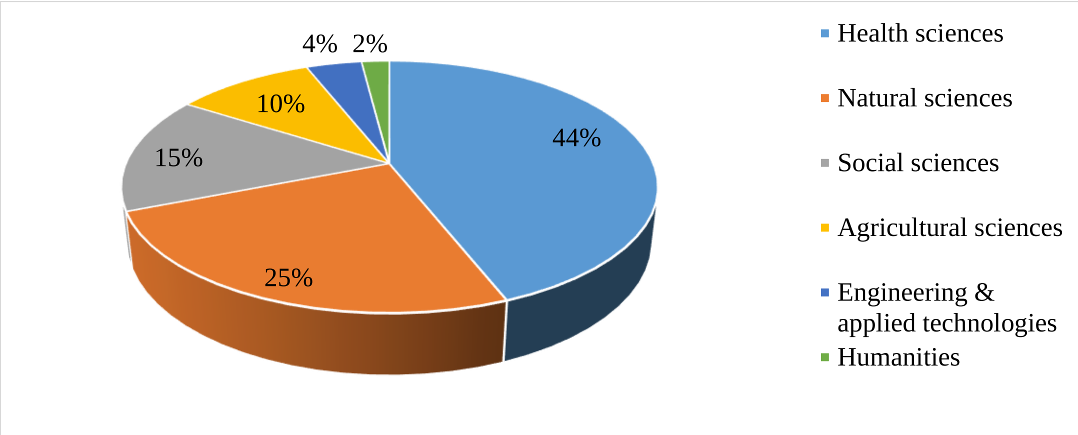

Figure 7.4: Average proportion of publication outputs across scientific fields for 2005–2018

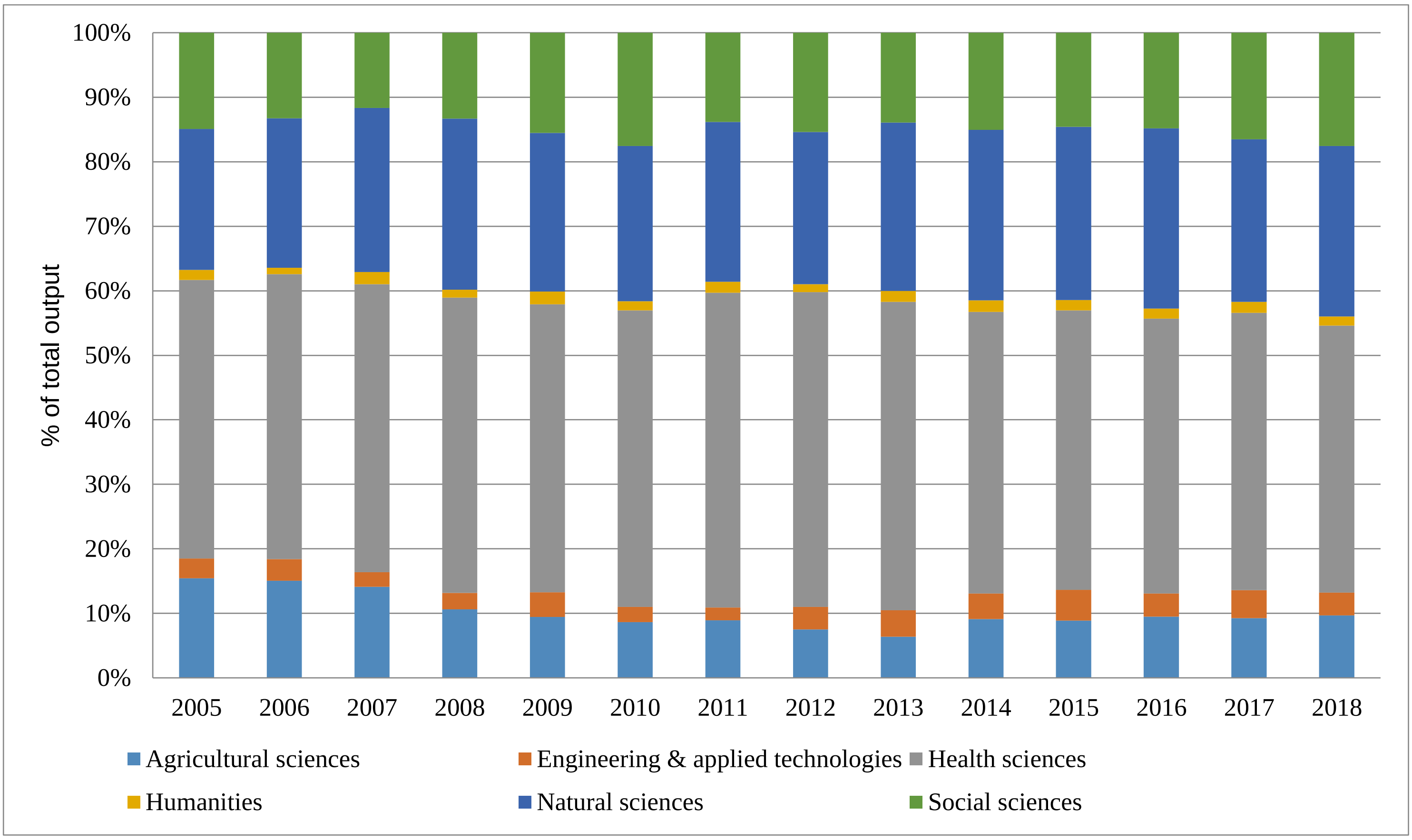

Figure 7.5: Publications by scientific field by year (2005 to 2018)

7.4 Most productive R&D institutions in Tanzania

Our analysis of output by research performing institution shows that the Muhimbili University of Health and Allied Sciences (MUHAS) was the most prolific institution over this time period by producing 575 publications, which constitute 16.1% of all publications. In close second place was the University of Dar-es-Salaam (UDSM), with publication of 566 papers, which constitutes 15.9% of all publications. SUA was the third in the number of publications by producing 460 papers, which is 12.9% of all papers. Other prolific institutions include NIMR which produced 11.8% of all publications and ranked fourth, and IHI that produced 8.0% of all publications and ranked in the fifth position.

In the recent period (2012–2018) MUHAS is again the most prolific R&D institution by producing 951 publications, accounting for 16.2% of all publications. The UDSM took the second position by producing 886 publications, which is about 15.1% of all publications. SUA is in the third position by producing 690 papers, accounting for 11.8% of all publication outputs, followed by NIMR, which produced 549 papers, which is 9.3% of all papers. The IHI produced 542 publications, accounting for 9.2% of all publications for six years. The IHI is one of the most prolific private research institutions in terms of scientific papers, where it ranked in the fifth position for the whole period. The study findings also indicate that the cumulative publications outputs almost doubled from 4226 to 7267 papers in the two window study periods, as Table 7.2 below displays. The overall top five most prolific R&D institutions in scientific papers over the period of 2005–2018, in order of prolificacy are the MUHAS, UDSM, SUA, NIMR and IHI.

Table 7.2: Tanzanian top performing research institutions 2005–2018.

2005–2011			2012–2018		
Institution	**No. of pubs**	**Rank**	**Institution**	**No. of publications**	**Rank**
MUHAS	575 (16.1%)	1	MUHAS	951 (16.2%)	1
UDSM	566 (15.9%)	2	UDSM	886 (15.1%)	2
SUA	460(12.9%)	3	SUA	690 (11.8%)	3
NIMR	421 (11.8%)	4	NIMR	549 (9.3%)	4
IHI	284 (8.0%)	5	IHI	542 (9.2%)	5
Kilimanjaro Christian Medical Centre	260 (7.3%)	6	Kilimanjaro Christian Medical Centre	372 (6.3%)	6
Ministry of Health and Social Welfare	157 (4.4%)	7	Ministry of Health and Social Welfare	256 (4.4%)	7
TUMA	122 (3.4%)	8	NM-AIST	222 (3.8%)	8
TAWIRI	93 (2.6%)	9	Kilimanjaro Christian Medical University College	181 (3.1%)	9
Ministry of Agriculture, Food Security and Cooperatives	89 (2.5%)	10	CUHAS	141 (2.4%)	10

2005–2011			2012–2018		
Institution	**No. of pubs**	**Rank**	**Institution**	**No. of publications**	**Rank**
Kilimanjaro Christian Medical University College	84(2.4%)	11	Muhimbili National Hospital	109 (1.9%)	11
Ministry of Livestock and Fisheries Development	55 (1.5%)	12	UDOM	108 (1.8%)	12
ARU	46 (1.2%)	13	Ministry of Agriculture, Food Security and Cooperatives	87 (1.5%)	13
CUHAS	42 (1.2%)	14	TAWIRI	86 (1.5%)	14
TAFIRI	41 (1.1%)	15	Mwanza Intervention Trials Unit	73 (1.2%)	15
Muhimbili National Hospital	36 (1.0%)	16	Buganda Medical Centre	71 (1.2%)	16
Haydom Lutheran Hospital	29 (0.8%)	17	TUMA	68 (1.2%)	17
TPRI	27 (0.8%)	18	Ministry of Livestock and Fisheries Development	65 (1.1%)	18
Ministry of Natural Resources and Tourism	27 (0.8%)	19	Kilimanjaro Clinical Research Institute	59 (1.0%)	19
UDOM	25 (0.7%)	20	TAFIRI	49 (0.8%)	20
Dar es Salaam City Council	19 (0.5%)	21	Ministry of Natural Resources and Tourism	48 (0.8%)	21
Helminth Control Laboratory in Zanzibar (Unguja)	19 (0.5%)	22	Haydom Lutheran Hospital	46 (0.8%)	22
St Augustine's Hospital Teule	18 (0.5%)	23	Weill Bugando University College of Health Sciences	45 (0.8%)	23
TAFORI	18 (0.5%)	24	Management and Development for Health	39 (0.7%)	24
Frankfurt Zoological Society, Tanzania	18 (0.5%)	25	TPRI	35 (0.6%)	25
Comprehensive Community Based Rehabilitation in Tanzania	18 (0.5%)	26	OUT	33 (0.6%)	26
Kongwa Trachoma Project	18 (0.5%)	27	Kongwa Trachoma Project	31 (0.5%)	27
			Ministry of Health, Zanzibar	30 (0.5%)	28
Total	**4226**		**Total**	**7267**	

7.5 Specialisation and visibility by scientific fields and sub-fields

Relative field strength (RFS) is a bibliometric indicator, which shows the strength or specialisation of scientific publications in a given domain, taking the world share as the baseline. The RFS is a measure of the effort or activity of a given country in a given scientific domain or sub-domain, relative to the effort of the reference entity (e.g. continent, the world) in the same scientific domain (AOSTI, 2014:4). A RFS score above 1 (world level) means that a given scientific field or subfield is specialized relative to the reference entity, while a score below 1 means the scientific field or subfield is not as active or specialized as the other fields in the country (compared to the world average for those fields).

The study findings indicate that over the decade of 2005–2018, the overall Tanzanian RFS of the agricultural sciences, health sciences and social sciences were above the world average values. However, the RFS of the agricultural sciences is lower in recent years (2012–2018) than during the previous period of 2005–2011. For instance, from 2005 to 2011 the RFS of agricultural science was 2.2, but then declined to 1.8 in the years 2012–2018). The RFS of the health sciences and social sciences have been sustained over the past decade as shown in Table 7.3 below.

It was also observed that the Tanzanian RFS in the natural sciences, humanities and the engineering and applied technologies were below the world average over the decade of 2005–2018 as Figure 7.6 and Table 7.3 below display. In other words, Tanzania is relatively weaker in the fields of natural sciences, humanities and engineering and applied technologies compared to the health sciences and agricultural sciences.

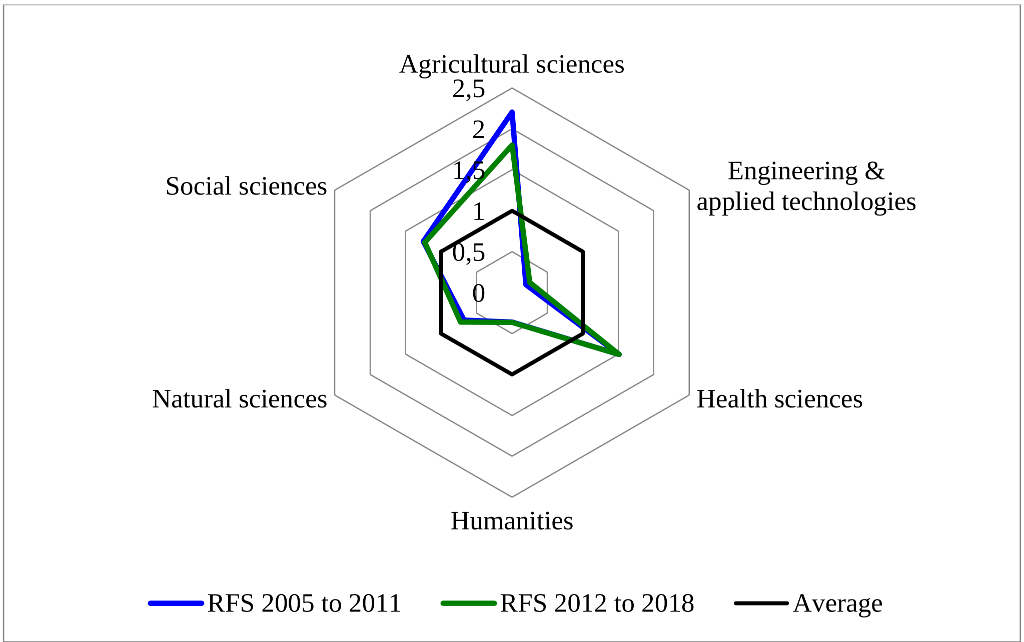

Figure 7.6: Relative field strength across all fields

Table 7.3: Tanzanian relative field strengths by scientific field

Scientific fields	RFS 2005–2011	RFS 2012–2018
Agricultural sciences	2.2	1.8
Engineering and applied technologies	0.2	0.2
Health sciences	1.5	1.5
Humanities	0.4	0.4
Natural sciences	0.7	0.7
Social sciences	1.2	1.2

7.6 Positional analysis

Positional analysis combines the citation impact of a field (as measured by the MNCS) with the RFS score a scientific domain. The fields that score high on both of these two indicators would typically be in the top right-hand quadrant (best-case scenario) as explained above (Figure 7.1). High impact, but not a specialised scientific domain, are located at the top left of the graph. Specialised, but low impact scientific fields below the world average, are located at the bottom right of the graph. Not specialised and low impact scientific domains, (worst-case scenario) are located at the bottom left of the graph.

Figures 7.7 and 7.8 compare the relative positions of Tanzania in the six fields mapped for two different time periods. The most salient finding is the improved position of the health sciences with an increase in citation impact.

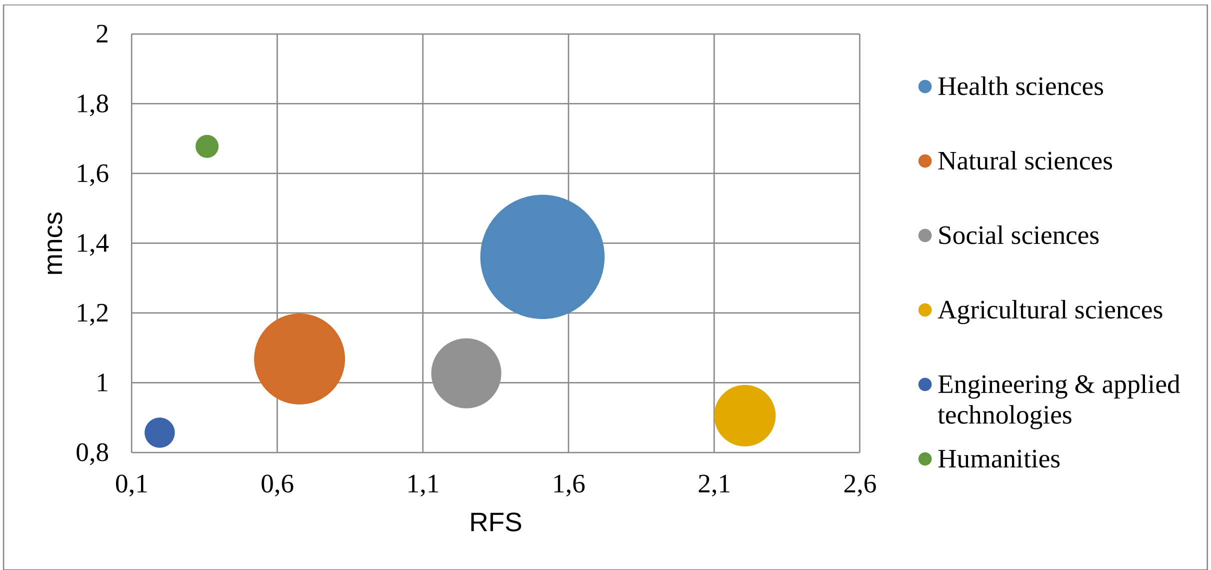

Figure 7.7: Positional analysis across all fields during the study period (2005–2011)

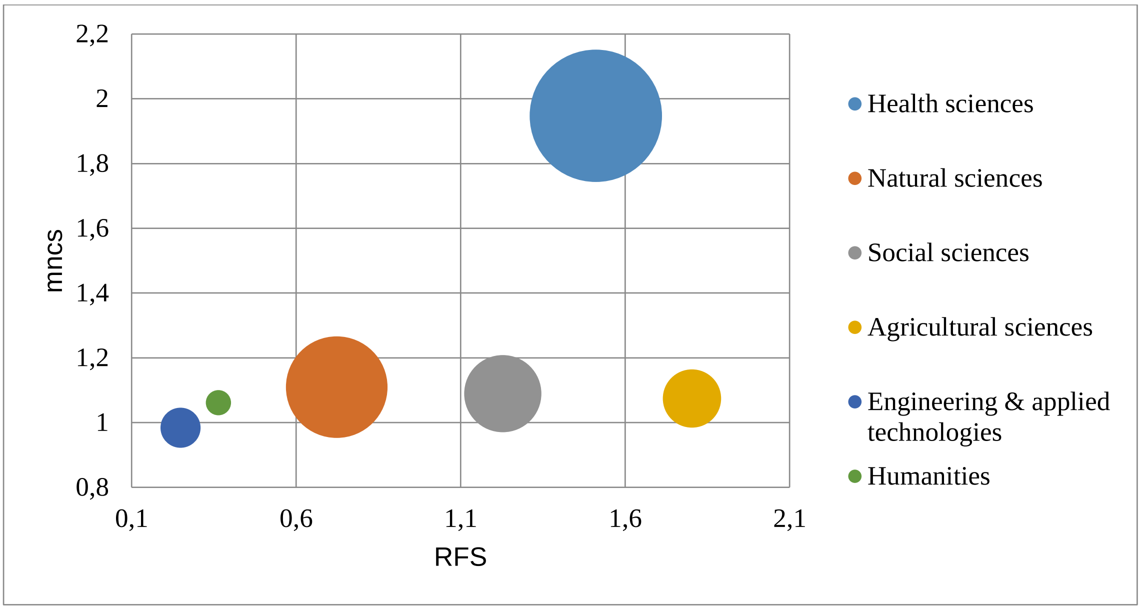

Figure 7.8: Positional analysis across all fields during the study period (2012–2018)

7.7 Publication trends by scientific field

In the final section we focus in more detail on the publication output (absolute counts, world share and RFS) and citation impact of the science main scientific fields.

Table 7.4: Summary view of publication outputs by scientific field

Field	Nr of articles		World share		Citation impact (MNCS)	
	2005	2018	2005	2018	2005	2018
Health sciences	168	681	0,05%	0,1%	1,2	1,7
Agricultural sciences	60	159	0,11%	0,15%	0,8	1,1
Social sciences	58	289	0,05%	0,1%	0,9	1,0
Natural sciences	85	434	0,02%	0,05%	0,6	0,8
Engineering sciences	12	58	0,01%	0,02%	0,3	0,8
Humanities	6	23	0,01%	0,03%	0,4	0,4

The salient points as presented in the Table above are the following:

- Across all six fields, we witness an increase in the numbers of publications between 2005 and 2008. However, it is still clear that Tanzanian science is strongest in the health sciences, followed by the natural and social sciences. Two fields – engineering sciences and humanities – continue to produce very levels of output.
- Tanzanian's share of world output in these fields has increased across fields. However, at the same time the country position on the world rank has declined suggesting that these increases did not stay abreast of the increased output of a number of comparator countries.

- A positive trend is the increase in citation visibility across all fields. This is positive development as it is most probably associated with the increase in international collaboration that was reported above.

7.8 Conclusions

Tanzanian scientific output as well as relative share of world publications increased in most all fields between 2005 and 2018. However, despite these increases, the country's overall rank in publication output declined from position 76 to position 80. This simply means that despite an increase in absolute publication output, the annual growth lagged behind the average growth in publications in many other countries and hence Tanzania's relative performance as measured in terms of country rank declined. Having said this, it is still encouraging that the publication output per million of the population has increased nearly threefold over the same period and that there is a noticeable improvement in the citation impact of the country's publications.

Our analysis of the RFS or activity index of the scientific fields in the Tanzanian system confirms the results of previous studies and shows that Tanzanian scientist produce relatively more in the fields of agriculture, health and social sciences. These remain the most active fields when compared to the world distribution by scientific field.

The results indicate that nearly half of all scientific publications (44%) in Tanzania are from the health sciences field, It is likely that a majority of these publications would report on clinical trials conducted in Tanzania, on tropical and other related diseases. The relative strength of this field can also be attributed to the existence of a small number of strong institutions, most notably MUHAS, NIMR, and IHI.

The broad domain of agricultural sciences in Tanzania remains a relatively active field with acceptable levels of citation visibility. The growth of scientific publications in agricultural sciences could be attributed to the increased research funding from within and outside the country as well as increased research collaboration in these fields. For example, between 2012 and 2016, the government of Tanzania and Sida, through COSTECH, funded about 100 agricultural research projects in different R&D institutions. The research projects could have contributed several publications outputs in the field of agricultural sciences. However, despite the specialisation in agricultural sciences in Tanzania, the production and productivity of the agricultural sector are still low, attributable to the low applications of agricultural technologies from R&D institutions. The sector contributes only 30% of the national GDP, regardless of about 70% of the national population being employed in the sector. It is important for the government and all stakeholders to promote and sensitise the applications of improved agricultural technologies to attain the full potential obtainable from the application of agricultural scientific outputs.

The fact that Tanzania remains relatively weak in the engineering sciences also means that the disciplines that traditionally form the platform for technology development and innovation are not strong. Unless these fields are strengthened the country will continue to lag behind on innovation.

CHAPTER 8: RESEARCH COLLABORATION

8.1 Introduction

Research collaboration across the globe has gained significant interest in recent years. In general, research collaboration seems to be increasingly related to conducting excellent research, exchanging knowledge, and sharing research facilities, and as such is an interesting goal to be undertaken through science policy (AOSTI, 2014:5). In recent years there has been an increase in research collaboration of African countries with developed countries. According to the 2014 Nature Index, 70% of Africa's research research output was produced through international collaborative research (Nature, 2015). Pouris and Ho (2014) study also indicated that the international collaborative publications increased by 66% to almost twice the growth of the single-country articles in Africa. Bibliometric techniques can be applied to measure collaboration between researchers, departments, R&D institutions or countries, through the analysis of bibliographic information contained in scientific publications with two or more authors (AOSTI, 2014:5. Notably, research collaboration is less frequent in certain scientific domains, for instance, experimental sciences collaborate more than theoretical sciences.

In this chapter, the bibliometric analysis was also applied to evaluate the performance of the Tanzania R&D institutions in terms of collaboration patterns across all scientific fields at a national level, African countries and countries outside Africa. Research collaboration among researchers at any level occurs in several ways, formal and informal, including being funded for a joint research project, sharing research equipment, writing a joint proposal, data exchange, exchange students and so on. However, despite the various facets of research collaboration, the measurable and visible indicator is a joint publication of scientific outputs (Sugimoto & Larivière, 2018:57). We used three indicators of collaboration:

<u>National collaboration rate:</u> The indicator shows the intensity of research collaboration between institutions within a single country. The rate is calculated by dividing the number of scientific publication outputs with at least two institutional addresses within the country by the total number of publications from that country.

<u>African collaboration rate (collaboration only with African countries):</u> This indicator shows the intensity of research collaboration between authors from more than one African country. In this study, this indicator reflects Tanzanian publications with one or several authors affiliated with more than one African country.

International collaboration rate (collaboration with countries outside Africa): This is an indicator that displays the intensity of research collaboration between researchers from an African country with researchers from outside Africa. In this context, the indicator shows the research collaboration rate between authors from Tanzania and at least one author from outside Africa.

The scientific fields in this study have been classified into six groups, namely the agricultural sciences, health sciences, natural sciences, social sciences, humanities, and engineering and applied technology. Authors with an affiliation to a Tanzanian address was one of the criteria for the extraction of the bibliometric data. Therefore, this analysis chapter sought to analyse the Tanzanian research collaboration profiles by finding answers to the research questions indicated in Table 8.1 below.

Table 8.1: Conceptual framework outlining the main themes and sub-themes for the analysis and findings of the survey and bibliometric analysis.

Main themes	Sub themes	Research questions	Applied tools
Research collaboration	Research collaboration profile and intensity	• What are the research collaboration rates in Tanzania (national, regional and international)? • How do research collaboration patterns differ between different scientific fields? • Is there an association between receiving research funding and collaboration?	Bibliometrics Survey analysis
	Gender difference, research funding and collaboration	• Are there gender differences in research collaboration?	

8.2 Overall publication collaboration profiles across scientific fields

The results show that Tanzanian scientists collaborate predominantly with authors from countries outside Africa. Over the period of 14 years (2005–2018), the share of Tanzanian collaboration with countries outside Africa, was between 76% and 82%, with an average of 79%**.** The proportion of national collaborations was between 8% and 12% with an annual average of about 10%. The findings indicate that the Tanzanian share of collaboration with African countries ranged from 3% to 7%, with an annual average of about 5%. The results also show that the proportion of single-authored papers ranged between 3% and 8% (Figures 8.1 and Figure 8.2).

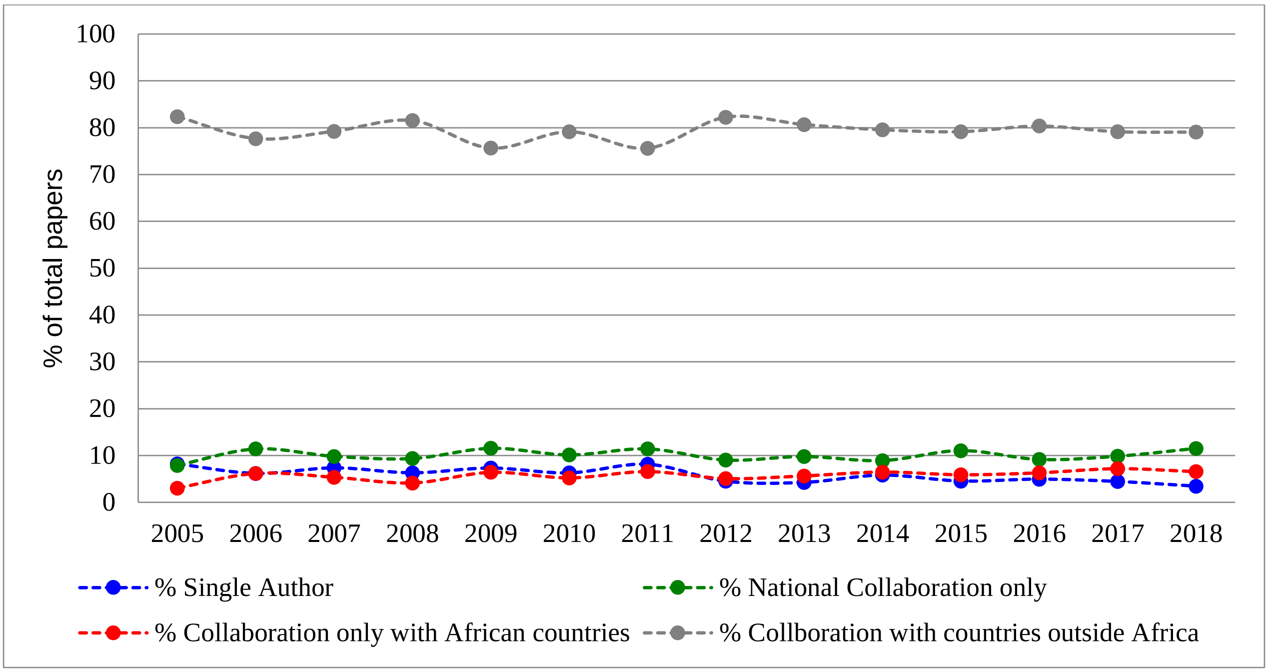

Figure 8.1: The overall Tanzanian collaboration profile from 2005–2018

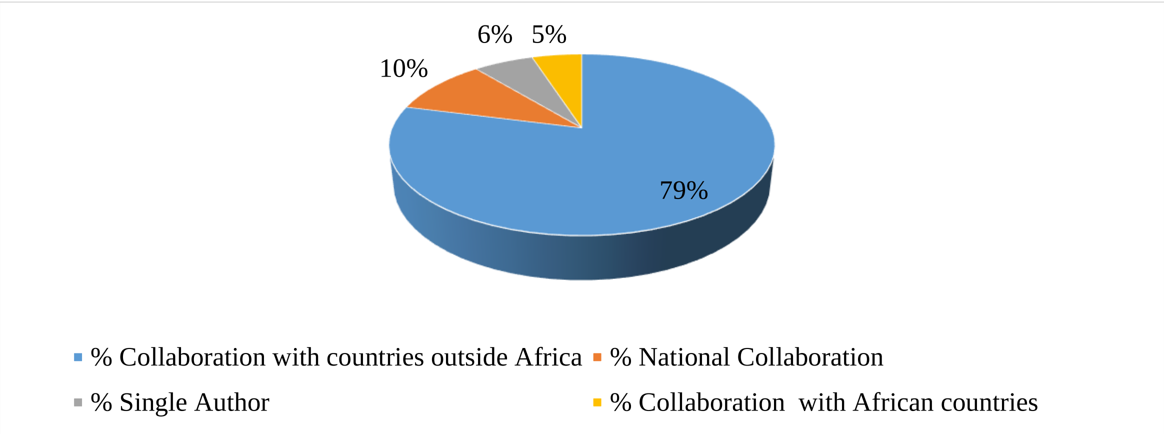

Figure 8.2: The overall Tanzanian collaboration profile from 2005–2018

Note:

- Single author: No collaboration
- National collaboration only: Collaboration between institutions in Tanzania
- Collaboration only with African countries: Tanzanian publications with one or several authors affiliated to more than one African country
- Collaboration with countries outside Africa: Publications comprised of Tanzanian authors and at least one author from outside Africa.

We also analysed the differences in collaboration trends across scientific fields as it is well-known that the publication practices (and hence the tendency to co-author) differ significantly across disciplines. The results were mainly as expected (Figure 8.3):

The bibliometric results indicate that, with the exception of the humanities, all of the other fields recorded high rates of international collaboration (the highest for the health sciences and natural sciences). Single-authored articles remain the preferred mode of publication of the Humanities.

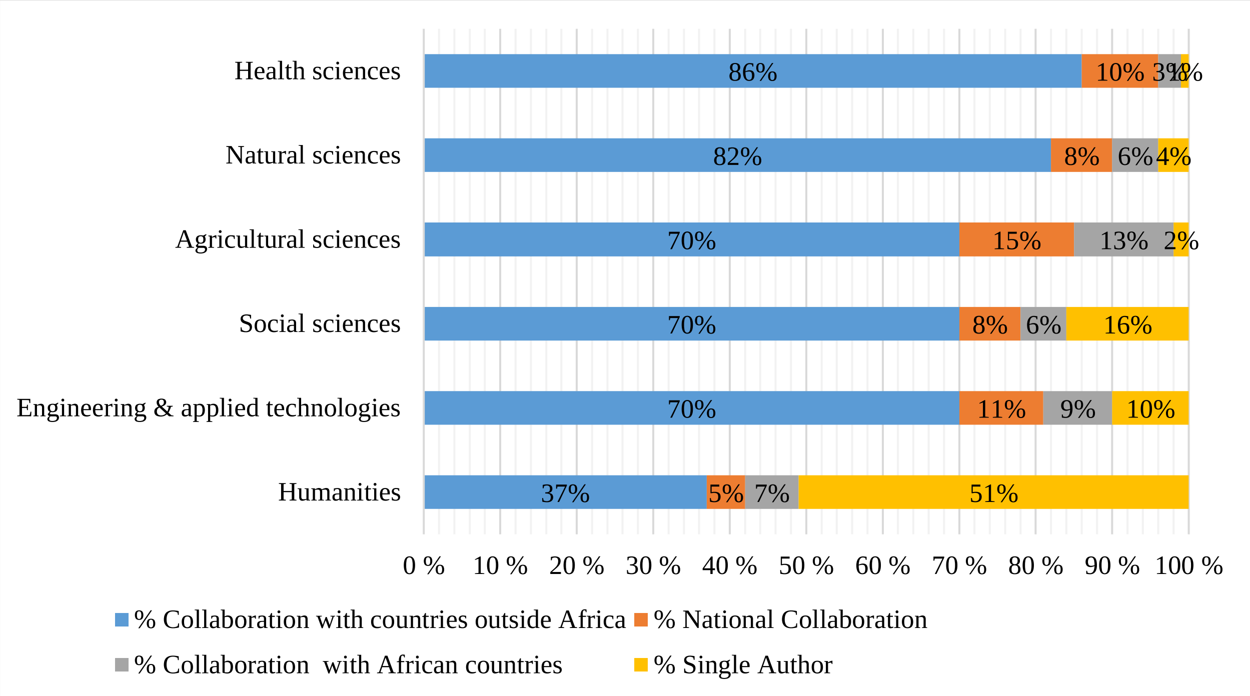

Figure 8.3: Collaboration patterns across the scientific fields: 2005–2018.

In the graphs below we compared the profile of collaborating countries for the early period between 2005 and 2011 with the later period (2012 – 2018). In the early period Tanzanian authors co-authored more frequently with authors from the United States and the United Kingdom followed by Sweden, Norway, Iceland, Switzerland, and the Netherlands. The third highest category of countries regarding collaboration were Canada, Belgium, Denmark, Germany and Japan. For the same period (2005–2011), the top 'collaborating African countries' were Kenya, Uganda and South Africa (Figure 8.4).

A very similar profile was found for the most period with the highest co-authored papers recorded with the United States and the United Kingdom. The second category with high collaboration intensity with Tanzania included Sweden, Norway, Germany, Iceland and Switzerland. As far as co-authoring papers with scientists from other African countries, we found that Kenya, Uganda, South Africa and Ghana topped the list (Figure 8.5).

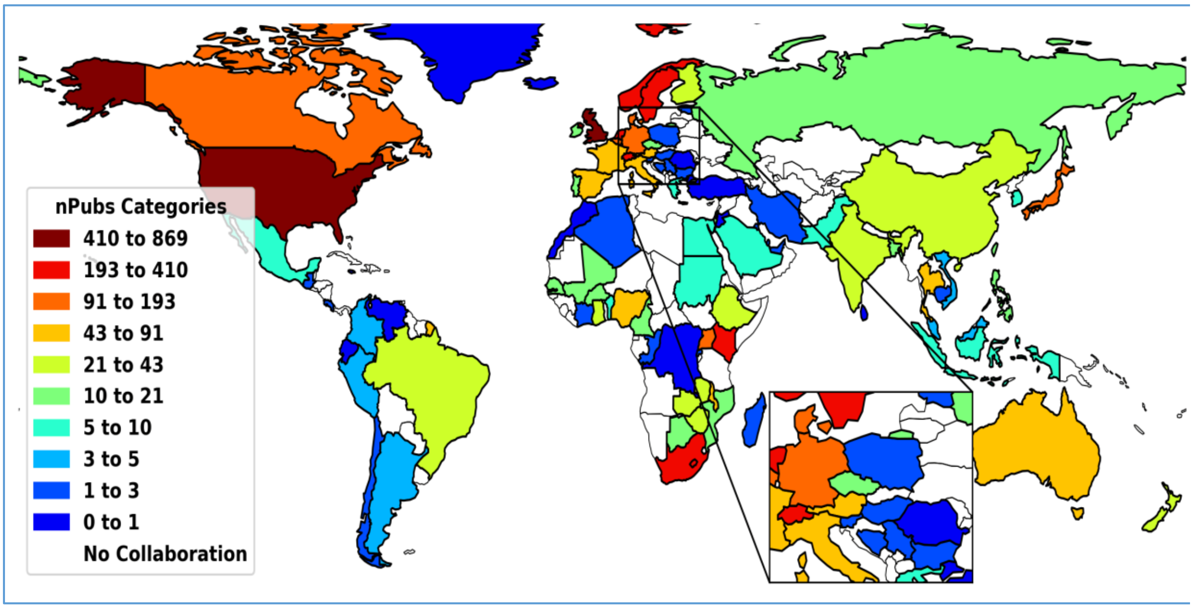

Figure 8.4: Collaboration intensity with other countries between 2005 and 2011

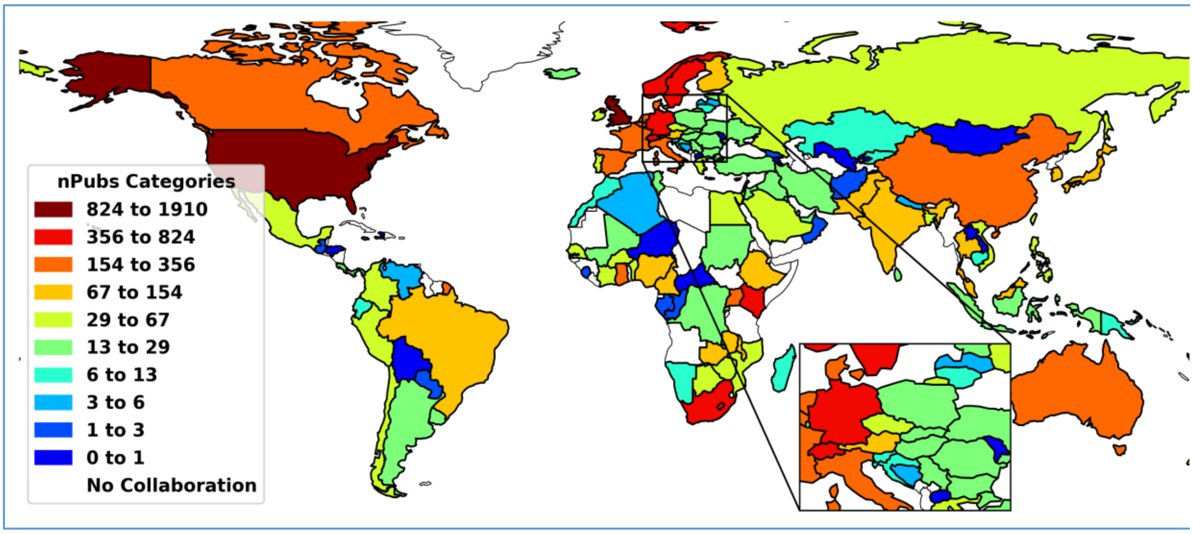

Figure 8.5: Collaboration intensity with other countries between 2012 and 2018

In closing it is important to make two cautionary notes about the results presented above: First, we only measure 'research collaboration' through the indicator of 'co-authorship'. This is of course, a reduced and simplified understanding of what 'true' collaboration in science means. This single indicator does not necessarily capture other form of research collaboration between scientists – joint research proposals, joint funding, exchange visits between centres, sharing of research infrastructure and equipment and so on. Second, the increase in international research collaboration as discussed above – especially in the health and agricultural sciences – should not be interpreted as a substantial and contentful increase in colaborative research practices. It is often the case that scientists from across the globe in these fields co-author papers that are based on small contributions of data or specimens or experiments where 200 to 300 scientists are funded under mega-projects. This is especially true of clinical trials where the contirbution of each author (besides the principal investigator) is relatively 'minor'.

8.3 Survey findings on research collaboration

This section presents the results of analysis of the survey where respondents reported on their collaborative practices. It is important to emphasize that the results presented here represent the self-reporting by respondents which may or may not be more subjective than the bibliometric results and certainly needs to be interpreted more cautiously.

Under this section of the analysis, the following issues have been explored and presented:

i. Reported research collaboration in Tanzania (national, regional and international);
ii. Gender differences in research collaboration.
iii. An association between reporting on research funding and collaboration;

8.3.1 National and international collaborations

The results from Figure 8.5 below suggest that the majority of respondents (n = 81, 68%) often collaborate in joint research or publications with researchers at their own institutions. The second group of researchers with the highest reported collaborations are those who collaborate often with counterparts from outside African countries (n = 63, 54%), followed by the national collaboration with other institutions within the country (n = 52, 43%. The results also suggest that the proportion of Tanzanian researchers who do collaborative research with researchers from other African countries is the lowest category (n = 41. 35%). Additionally, the results indicate that the proportion of single-authored papers (those who never co-author papers) is the lowest.

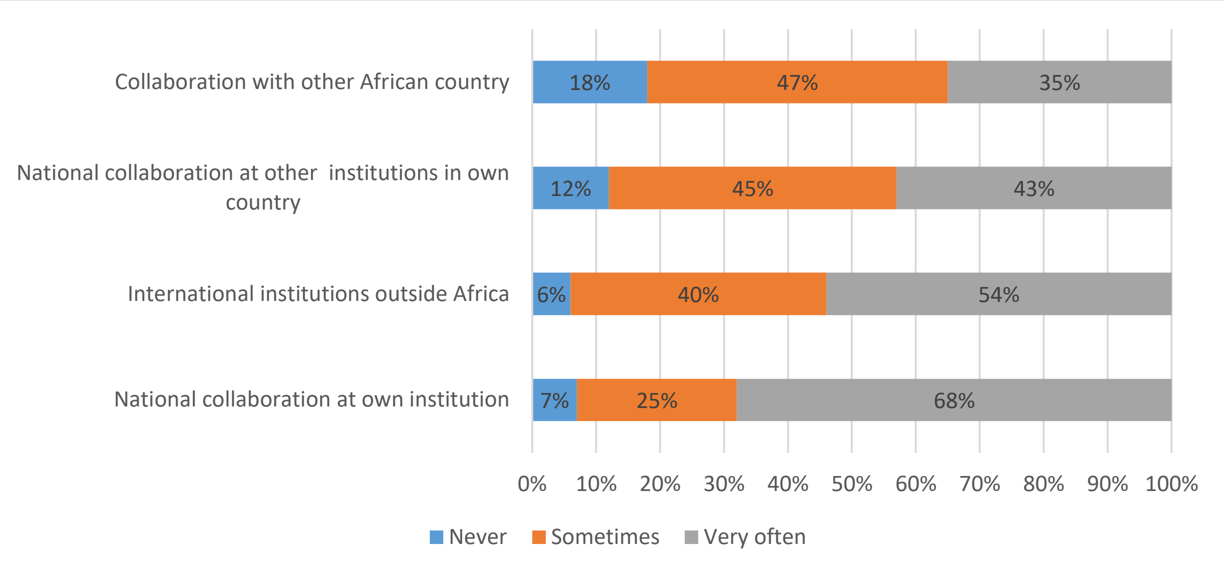

Figure 8.6: Types of reported collaboration

8.3.2 Gender difference on research collaboration

This study also examined whether there are gender differences in reported research collaborations. The null hypothesis is that there is no significant gender difference in collaboration between the male and female respondents. The proportion of males and females in the survey data was 67% and 33% respectively.

The results in Table 8.2 clearly show that the proportions of male and female respondents on collaboration are more or less the same as the proportion of male and female in the sample. And these are the same across all four response options. No statistically significant differences were found between male and female respondents when reporting on collaboration within their own institutions, or collaboration with researchers at other institutions in their own countries, or collaboration with researchers at institutions in other African countries or collaboration outside Africa.

Table 8.2: Proportion of collaboration by gender

Collaboration profile	Gender						
	Male		Female		Subtotal		
	Count	Row %	Count	Row %	Count	Row %	P value
Researchers at own institution	73	68%	34	32%	107	100%	0.44
Researchers at other institutions in own country	69	68%	33	32%	102	100%	0.77
Researchers at institutions in other African countries	61	65%	33	35%	94	100%	0.38
Researchers at institutions outside Africa	73	69%	33	31%	106	100%	0.21

8.3.3 Research collaboration and funding

The analysis of research collaboration and funding sought to assess if there is an association between receiving research funding (primary recipient or sometimes not primary recipient) and collaboration. Of the respondents who showed in the past three years (2014–2016) that they collaborated nationally at their own institutions, those who were in some cases primary or not primary recipients, accounted for the highest proportion (n = 78, 70.3%) as shown in Table 8.3 below. A small proportion (n = 33, 29.7%) of respondents who received no funding collaborated nationally at their own institution for the past three years. Additionally, the findings indicate that about 75% of respondents who did not collaborate received no funding, while only 25% of respondents received funding without collaboration. When the national collaboration at their own institution were cross-tabulated by receipt of research funding, the results indicate that there is a statistically significant difference in receiving research funding and collaboration (Fischer's exact test, p = 0.015). The respondents who collaborated in the past three years, received more funding than those who never collaborated.

Table 8.3: National collaboration (own institution) by funding

National collaboration – own institution	No		Yes, primary recipient or sometimes not primary recipient		Subtotal	
	Count	Row %	Count	Row %	Count	Row %
Never	6	75.0%	2	25.0%	8	100%
Yes	33	29.7%	78	70.3%	111	100%
Subtotal	39	32.8%	80	67.2%	119	100.0%

Of the respondents who showed in the past three years (2014–2016) that they collaborated nationally with other institutions, those who were in some cases primary or not primary recipients, still accounted for the highest proportion (n = 74, 69.8%). Again, a small proportion (n = 32, 30.2%) of researchers who received no funding, collaborated nationally with other institutions for the past three years. Furthermore, the results in Table 8.4 below reveal that about 57.1% of respondents who did not collaborate, received no funding while a fair proportion of 42.9% of respondents received funding with no collaboration. When national collaboration with other institutions was cross-tabulated by research funding, the findings show that there is no statistically significant difference in receiving research funding and collaboration (Fischer's exact test, p= 0.068).

Table 8.4: National collaboration (other institutions) by funding

National collaboration – other institutions	No		Yes, primary recipient, sometimes not primary recipient		Subtotal	
	Count	Row %	Count	Row %	Count	Row %
Never	8	57.1%	6	42.9%	14	100%
Yes	32	30.2%	74	69.8%	106	100%
Subtotal	40	33.3%	80	66.7%	120	100.0%

Of the respondents who showed in the past three years (2014–2016) that they collaborated with institutions in other African countries, those who were in some cases primary or not primary recipients, accounted for the majority (n = 68, 70.8%) as indicated in Table 8.5 below. Less than one third (n = 28, 29.2%) of respondents who received no funding collaborated with researchers from other African countries. Moreover, when collaboration with researchers from other African countries was cross-tabulated by receiving research funding, the findings demonstrate that there is a statistically significant difference in receiving research funding and collaboration (Chi-square test, p = 0.041) with researchers from other African countries outside Tanzania. Under this category of research collaboration, the respondents who collaborated in the past three years were more likely to have received funding than those who never collaborated.

Table 8.5: Frequency of international collaboration (other African countries) by funding

International collaboration, other African countries	No		Yes, primary recipient, sometimes not primary recipient		Subtotal	
	Count	Row %	Count	Row %	Count	Row %
Never	11	52.4%	10	47.6%	21	100%
Yes	28	29.2%	68	70.8%	96	100%
Subtotal	39	33.3%	78	66.7%	117	100.0%

Of the respondents who showed that in the past three years (2014–2016) they collaborated with institutions outside African countries, were in some cases primary or not primary recipients, accounted for the major proportion (n = 78, 70.9%) as Table 8.6 displays. Again, less than one third (n = 32, 29.1%) of respondents who received no funding collaborated with researchers outside African countries. The findings also indicate that the majority of respondents (85.7%) who did not collaborate, received no research funding. Moreover, when collaboration with researchers from countries outside Africa was cross-tabulated by receiving research funding, the findings indicate that there is a statistically significant difference in receiving research funding and collaboration (Fischer's exact test, p= 0.005) with researchers from countries outside Africa. Again, under this category of research collaboration, the respondents who collaborated in the past three years, received more funding than those who never collaborated.

Table 8.6: Frequency of international collaboration (outside Africa) by funding

International collaboration – outside Africa	No		Yes, primary recipient, sometimes not primary recipient		Subtotal	
	Count	Row %	Count	Row %	Count	Row %
Never	6	85.7%	1	14.3%	7	100%
Yes	32	29.1%	78	70.9%	110	100%
Subtotal	38	32.5%	79	67.5%	117	100.0%

8.4 Discussion

On research collaboration, the bibliometric study reveals that over the decade (2005–2018) the collaboration rate of Tanzanian authors with authors outside Africa was about 79%. The proportion of publications with the national collaboration was 10%, while the Tanzanian share of collaboration with African countries was about 5%. The Onyancha and Maluleka (2011) study also reveals that the publications production through co-authored research between researchers from sub-Saharan African, nations is insignificant. The highest collaboration intensity of the country with countries outside Africa, especially the north, is not a surprising result, simply because developed countries influence poor countries through the significant availability of research funding (Boshoff, 2009:482). There are several motives for research collaboration. According to several sources (Narin et al., 1991; Pao, 1992:100), research collaboration can improve the impact and recognition of scientists and allow sharing of expensive research facilities and equipment. The low collaboration profile of Tanzania with other African countries as a whole, is not a good indicator of the regional development on STI. Intra-Africa research collaboration should be promoted, simply because it is important for developing solutions and needs of developing countries, whilst optimising the use of limited resources (Ohiorhenuan & Rath, 2000; Kane, 2000).

The findings of this study have shown that the top two collaborating countries with Tanzania over the decades (2005–2018) were the United States and the United Kingdom. Similarly, the findings by Toivanen and Ponomariov (2011:477) reaffirm that the top collaborating countries with Tanzania are the United States and the United Kingdom. Other countries with significant collaboration with Tanzania are Sweden, Norway, Denmark, Iceland, Switzerland, the Netherlands, Belgium, Germany, Italy, France, Spain, Japan, Australia and Canada. The long-term cooperation of Tanzania with the Nordic countries (Sweden, Norway, Denmark and Iceland) could likely contribute to the extensive research collaboration between the countries. The top African collaborating countries with Tanzania were Kenya, Uganda and South Africa. We also found that collaboration intensity increased in recent years.

The collaboration of Tanzanian authors with international counterparts in the health sciences is the highest among scientific fields. Our findings also has indicated that over the last 14 years (2005–2018), the top three collaborating countries with Tanzania in the field of health sciences were the United States, the United Kingdom, and Switzerland. Tanzanian and Swiss collaboration is likely to be through the Ifakara Health Institute, where several research projects on tropical diseases are conducted. The Ifakara Health Institute (the former Swiss Tropical Institute Field Laboratory) was a part of the Swiss Tropical Institute (STI), and still gets substantial support from Switzerland. The second top countries category with high collaboration with Tanzania in the field, were Norway, Sweden, Denmark, Iceland, Germany, the Netherlands, Belgium, Austria, Canada, and Australia. The funding support from Sida, NORAD, DANIDA, DAAD, GETZ and other funding sources from Europe, could likely contribute to the high collaboration intensities of Tanzania with the aforementioned European countries. Kenya, Uganda and South Africa are the top African collaborating countries. The high collaboration rate of Tanzania, Kenya, and Uganda could be attributed to the strong colonial relations since the British administration before Tanzanian independence. During colonial administration, research was conducted and coordinated for the mutual benefit of all three member states by the East African High Commission between 1948 to 1961. After independence, in the East African member countries, research was jointly coordinated by the East African Common Services Organization, and thereafter (1967–77) under the East African Community (EAC) which was dissolved in 1977 (COSTECH, 2007). The EAC was then re-established in 2000 and the former member states are collaborating in several matters, including research coordination. The high collaboration rate of Tanzania with South Africa could be contributed to the existing bilateral research cooperation between the two counties through COSTECH and NRF South Africa. Moreover, South Africa is a hub for Ph.D. training on the African continent in which Ph.D. students come from other African countries, including Tanzania. Tanzanian Ph.D. alumnae in South African universities are also likely contributing to the substantial collaboration intensity between Tanzania and South Africa through collaborative research projects.

In the agricultural sciences over the past 14 years, the Tanzanian average collaboration intensity with overseas countries was about 70%. The Tanzanian collaboration profile in the agricultural sciences with other African countries was at an average of 13%, national collaboration 15%, and single-authored papers 2%. Like in the health sciences, the top collaborators with Tanzania in the field of agricultural sciences were the United Kingdom and the United States. As previous studies noted (Toivanen & Ponomariov 2011; Megnibeto 2013), this is not a surprise as it could be expected of the impact of the British colonial legacy in research collaboration, particularly with Anglo-Saxon countries (UK, USA, Australia, and Canada). Other countries were Denmark, Norway, Iceland, Belgium, Germany, the Netherlands and Japan. The top African collaborators were Kenya, Uganda and South Africa. It was also noted that collaboration intensity was higher in recent years, when compared with previous years.

According to the study by Mouton, Prozesky and Lutomiah (2018) the findings show the association between research collaboration and funding. The study noted that African scientists engage in collaborative research in order to access more research funding from international sources. The analysis of survey results on research collaboration has shown that there are statistically significant relationships between respondents receiving funding and the frequency of researchers to do collaborative research. This implies there is an association between receiving research funding and national collaboration with researchers at their own institution, international collaboration with institutions in other African countries, and internationally from countries outside the African continent.

The findings also suggested that the proportion of male and female scientists in collaboration intensity is more or less the same. The majority of respondents in the sample were males (67%), and the proportion of females was 33%. The findings reveal no significant difference between male and female respondents in collaboration at all four categories of collaborations (at their own institution, at other institutions in their own country, at institutions in other African countries, and collaboration of researchers at institutions outside Africa). This implies that in Tanzania there are no gender differences in research collaboration. Both genders collaborate proportionally.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

9.1. The aim and relevance of the study

The research study was inspired and motivated by the absence of a comprehensive research study on the state of science in Tanzania. Only a few bibliometric studies with limited scope in terms of scientific fields, the number of institutions, and coverage in time have been done so far. The study sought to assess the state of the Tanzanian science system and analyse the characteristics of research investment, its human resources, research performance, and challenges that affect the research performance of scientists in R&D institutions. The study employed basic scientometric and bibliometric methods to examine the research investment, human resources capacity in R&D institutions, trend of scientific papers, and distribution across the scientific fields, top-performing R&D institutions, citation impact, relative field strengths, positional analysis across scientific fields, and collaboration patterns from 2005 to 2018. The study also analysed the secondary survey data from scientists in Tanzanian R&D institutions to find out the factors influencing the performance of researchers and their career development.

9.2 Main findings and conclusions

Our final assessment of the state of the science system in Tanzania is, perhaps not surprisingly, a mixed one. We have found evidence of positive and encouraging trends, but at the same time also of negative and disappointing performance. To present these results in a systematic manner, we use the standard SWOT framework to summarise our main findings.

Table 9.1: The SWOT analysis of the main findings of the study

Strengths	Weaknesses
• Available S&T policy, legal and institutional frameworks • Established funds for S&T (NFAST) • Functional national coordinating body for STI (COSTECH) • Long history of science in Tanzania and articulated institutional landscape • High collaboration of R&D institutions with overseas counterparts • Available personnel in R&D institutions • Relative activity in health, agriculture, and social sciences	• Low expenditure on R&D • Dilapidated research infrastructures and equipment • Overdependence of funding from external sources • Insufficient human resources in R&D • Weak linkage of R&D institutions and COSTECH • Lack of mentorship and skill development programs for young scientists • Lack of knowledge database
Opportunities	**Threats**
• To increase bilateral and multilateral collaboration with African countries • More collaborate of R&D in the country to with world class R&D institutions • To secure more research funding from external sources • Available technical assistance from external organization e.g. UNESCO, NRF • To increase the commercialization of research outputs (knowledge, services and products) • The country to become a science hub	• Implementation of research to suit external agenda • Brain drain of scientists • Decrease of students enrolments in STEM • Overdependence of imported technologies to solve local problems • Decline in the quality of students after graduation. • Decline in the impact and strengths of many scientific fields

The SWOT analysis shown in the table above provided a snap short of the state of Tanzania science system. We elaborate on each of these below.

Strengths

The country's S&T policy, legal and institutional frameworks are in place which are used in the governance and implementation of science, technology, and innovation programs. Most of the legal and institutional frameworks were promulgated a few years after the country's independence. However, some institutional frameworks were in place before independence during the British East Africa administration. This meant that the major actors in the science system inherited and still have a well-defined mandates and roles in the governance and implementation of STI programs. The national fund for the advancement of science and technology (NFAST), which was established in 1995, is an indication of the government's commitment to funding R&D institutions to conduct research activities, provision of research equipment, and so on. The major funder of the NFAST is the government, however, the study has shown that the funding disbursement from the government remain very small and does not meet the R&D demands of the country.

The establishment of COSTECH in 1986, which is mandated to coordinate, promote, and popularized science, technology, and innovation in the country is assessed to be a positive feature and strength in the national science system. The Chief Executive Officer of the Commission is appointed by the President of the United Republic of Tanzania, this shows the importance of the Commission in the coordination of science, technology, and innovation in the country.

In my view, the long history of science in Tanzania provided a good legacy that would benefit research institutionalisation. The British and German administrations laid the platform for R&D institutions pre-independence. The colonial administrations established R&D institutions to control diseases, food insecurity, and demand for raw materials during the first industrial revolution in Europe. The establishment of R&D institutions was important to facilitate the mission of the colonial governments. However, the well-established and organized agricultural, livestock, and health research institutions in the country by the colonial masters is a legacy of the Tanzanian science system of today.

Although the number of personnel in the R&D institutions are insufficient, they conduct research activities when there is the availability of research funding. Our bibliometric analyses revealed increasing level of international research collaboration (as measured by co-authorship of scientific papers). These relatively high rates foreign collaboration with developed countries do provide opportunities to Tanzania researchers and their counterparts to exchange knowledge and experiences. Furthermore, through these collaborations, the Tanzanian researchers are able to benefit in securing research funding and gaining access to modern research facilities and equipment from well-resourced countries. The increased number of publication outputs four times over 14 years is attributable to several factors including the increased research collaboration rate, increased funding, increased number of R&D institutions, an increased number of R&D personnel. It is noteworthy that the country remains relatively active in the health sciences and agriculture sciences.

Weaknesses

The government's expenditure on R&D remains very low at 0.5% of GDP which is just half of the agreed target in the NEPAD agreement. The current Tanzania science and technology policy aspires to spending at least 1% of the GDP on R&D. However, the continued low GERD/GDP remain a big concern and reflects the lack of a strong commitment from the Tanzanian government to prioritise science amidst other national priorities.

The low levels of expenditure on R&D means a general lack of research funding and funding for research equipment in most of the R&D institutions. Dilapidated research infrastructures and equipment in most of the R&D institutions around the country in turn leads to insufficient production of knowledge and technologies. The survey findings from scientists also indicated that the lack of research funding is the most challenging factor which negatively influences their research performance and careers. The proper implementation of the country's science and technology policy among other things it also requires the availability of enough funding for R&D. Additionally, the overdependence of research funding from foreign sources may jeopardize the implementation of research activities based on the country research agenda. The findings have shown that most of the foreign funding sources have specific objectives and agenda which may not necessarily be aligned with the country research priorities.

As far as human resource capacity is concerned, our study has shown that the country has an insufficient number of R&D personnel when compared to several African countries. Additionally, the low proportion of R&D researchers with Ph.D. qualifications (25%) in the country is not a good indicator – especially of the top universities in the country. Adequate numbers of highly-qualified R&D personnel remains the key to excellence in science.

COSTECH is a national coordinating body on all matters on science and technology it needs to have a strong bond with R&D institutions in the country. In my findings and other previous studies have shown that there is a weak linkage between COSTECH and R&D institutions in Tanzania. For instance, R&D institutions in the country are not legally obliged to furnish information to COSTECH related to research funding, human resource capacity, publication performance, and so on. This is one of the challenges during the collection of STI indicators through R&D survey exercises in the country. Furthermore, a knowledge database is an important STI infrastructure. The database can keep country STI indicators which are important for monitoring and evaluation of the science system. Tanzania has no such database. It is noteworthy that the UNESCO Institute of Statistics (UIS) database shows very little data from the Tanzania R&D system, simply because of the unavailability of STI data. The country needs to establish the necessary infrastructure required for the collection, archiving and processing of STI indicator statistics. This will easily allow benchmarking R&D performance of the country with other countries.

The Lack of mentorship programs and training to develop professional skills for young scientists are another major factors which influence negatively the research performance of young researchers in R&D institutions in Tanzania. The low performance of scientists can lead to the production of low quantity and quality of knowledge and technologies in the country.

Opportunities

The study findings identified several opportunities that can improve the state of the Tanzania science system. The findings have shown that the Tanzania research collaboration intensity with other African countries is low (5%). Through regional cooperation platforms (e.g. SADC, NEPAD, SGCI, EAC) the country could increase bilateral and multilateral research collaboration with African countries. The intra Africa research collaboration could help to create knowledge and solutions to solve our local challenges. On the other hand, the country's overseas research collaboration intensity is high (79%). It is advantageous for R&D institutions in the country to increase collaboration with world-class R&D institutions. This will increase the impact and strength of the produced knowledge of Tanzania. Additionally, through collaboration with overseas institutions, Tanzanian R&D institutions could benefit more from research funding, access to modern research infrastructures, and equipment from developed countries. It is noteworthy that, balancing the benefits of research cooperation with other countries is important. Therefore, the country and participating R&D institutions have to create a win-win situation to benefit from research collaborations. Another opportunity that can be used to improve the state of science in Tanzania is to use the available technical assistance from regional and global organizations (e.g. SADC, NEPAD, NRF- South Africa, UNESCO to mention a few). For instance, through the technical and financial assistance from UNESCO, the country managed to review its NSI in 2013. Additionally, the technical assistance from NEPAD and financial support from Sida in 2014 improved the R&D survey in the country. Therefore, it is important to take advantage of available regional and global partners in R&D to improve the Tanzanian science system.

The current state of commercialization of research outputs in the country is very low. According to URT (2012:67), most of the research projects conducted in the country are not demand-driven but are done for the sake of curiosity and publications. The country has an opportunity to increase the commercialization of research outputs (knowledge, services, and products) to solve the prevailing challenges of the country and at the global level in general. Additionally, there is an opportunity to become a science hub for the social-economic development of the country. The country could strategically invest in high-level training to increase the critical mass of scientists in R&D institutions and hence facilitate the establishment of science hubs. The science hub could increase the production of products and services for commercial purposes.

Threats

In the assessment of the Tanzania science system, the study findings have also shown several threats. The first threat is the exclusive implementation of donors' research agendas and ignoring national agenda's and priorities. Insufficient research funding and low spending on R&D in the country force researchers to look for funding from external sources.

The lack of research funding and a poor working environment could also cause "brain drain" of scientists in R&D institutions by finding more paying jobs within and outside the country. For instance, in recent years there are many senior scientists and professors from R&D institutions in Tanzania who left their jobs and became politicians to secure better remunerations. This situation has serious consequences for R&D institutions since it takes a long time with huge financial resources to train a scientist.

The poor working environment of scientists and dilapidated research equipment in higher learning institutions may discourage enrolment of students in science, technology, engineering, and mathematics (STEM). STEM is crucial in the development of science, technology, and innovation. Insufficient scientists trained in STEM could lead the country to over dependence on imported technologies to solve local problems and hence damage the country's science system. Additionally, poor research infrastructure and insufficient teaching facilities in higher learning institutions could decrease the quality of graduating students and become uncompetitive in the local and international job markets. the lack of funding and poor working environment in R&D institutions in Tanzania could lead to a decline in the research performance in R&D institutions.

9.3 Contribution of the study

The research presented in this dissertation contributes to knowledge in both methodological and empirical evidence about the state of science in Tanzania. Methodologically (mixed methods approach), the research has provided comprehensive findings on the research investment, research capacity, research outputs, and the barriers that affect the performance of scientists in Tanzania. Bibliometric and R&D data have several limitations. As indicated above, the analysis of the Tanzanian human resources and GERD in this study used 2013 data, which is the latest data available, and therefore requires to be triangulated with data from other sources. The methodological contribution of this study refers to the integrative application of datasets from both survey, a historical review of science and bibliometric), this study, therefore, makes an important methodological contribution to assessing the state of science in the Tanzanian context. Additionally, in the assessment of the Tanzanian research performance, this study makes an important methodological contribution in conceptualising and operationalising selected research and innovation category indicators, such as research investment, human resources capacity, research publications, and scientific impacts. The conceptual framework used in this study to assess the performance of research was adopted from the framework developed by Mouton (2015), which is suitable for the contexts of developing countries. Conventionally, the research evaluation framework embedded in the Frascati manual developed by OECD is normally used to assess research performance of a country.

Scientometric studies in Tanzania are still at the embryonic phase, there are very few studies which have been conducted so far. Previous studies were either confined in a single R&D institution or with a limited scope of scientific fields. To our knowledge, this is the first study to provide exhaustive insight into the state of science in Tanzania by the application of the scientometric method. The study cut across scientific fields, analysed R&D personnel, research collaboration intensity, research funding, and involved all major R&D institutions in the country. It is, therfore arguably, the most comprehensive study on the state of the Tanzanian research enterprise.

A final significant contribution of this study is that of an extensive review of the literature on scientometric studies that have been conducted in Tanzania, which adds to our understanding of the extent and magnitude of the application of the discipline to assess the research performance in the country. Furthermore, I consider a strength of the current study its identification of constraints underlying the research performance of scientists in Tanzania, and I have included measures to counteract the identified factors. Therefore, the recommendations provided by the study could contribute to improve the performance of the scientists in the Tanzanian science system.The findings of this study could also stimulate dialogue for policy changes and formulation of framework, guidelines policy brief to improve the science system in Tanzania.

9.4 Recommendations

Based on the findings obtained in this study, the following recommendations are made.

It is crucial for the government to increase the research and innovation investment from 0.53% to 1% of GDP, as aspired to by the national R&D policy and the NEPAD agreement. It is important to develop and promote a robust institutional framework for the mobilisation and management of STI financial resources, which target strategic national priority areas. The EAC sister country, Kenya, with more or less the same economic outlook like Tanzania, has increased its GERD to 0.79% of its GDP in 2016 and the target is to reach 2% by 2022 (AU, 2014:41).

Apart from the National Funds for Advancement of Science and Technology (NFAST) that is disbursed on competitive bases, the government needs to establish block research funding allocation to R&D institutions annually in order to increase research activities. It is recommended that the government, through NFAST, continue and increase the support for postgraduate studies (Masters, Ph.D., and postdoctoral fellowships) in order to increase the critical mass of researchers in R&D institutions. The national postdoctoral framework has been used to promote postdoctoral programmes in R&D institutions. For instance, the government of Kenya, through the National Research Foundation (NRF), supports the training of about 200 Ph.D. and 300 Master’s students annually (NRF, 2019).

The human resources in R&D institutions need to be increased. The research and innovation capacity of the country is lower than Kenya with more or less the same social-economic outlook as Tanzania. Therefore, it is important for the government to employ more staff in higher learning and research institutions to fill the gap and to attain the full potential obtainable from the application of STI for social-economic development, especially during this period when the country is striving to become a middle-income country through industrialisation by 2025.

The government needs to develop and implement human resource development programmes aimed at identifying, developing, acquiring, and retaining a highly skilled STI labour force in developing key competencies for innovation. This will support the execution of national priority targets.
Science-based monitoring and reviewing systems are essential for the success of STI policies and programmes. It is important for the government to develop a comprehensive performance management framework for monitoring and evaluation of STI policy implementation, STI programmes, and related initiatives.

It is crucial for COSTECH, as the national coordinating body on STI matters, to establish a knowledge database which will contain updated information on human resources capacity and scientific outputs (e.g. number, gender, age, available skills and level of education, publication outputs and so on) in R&D institutions. The collection of more critical STI data and information from the R&D institutions could improve the data quality and analysis, and hence be able to make some meaningful observations, conclusions, and recommendations, which are missing in this study. Additionally, the government has to conduct regular STI surveys to monitor and evaluate the progress of science and technology in the country.

Tanzanian scientists have to continue the engagement in collaborative research with counterparts from other nations to increase the research excellence and visibility of research outputs. On top of that, the country also needs to increase collaborative research with other African countries to tackle common challenges facing the continent since the country collaboration profile with other scientists from African countries is low. Young scientists in their early careers face professional development constraints (lack of mentoring, lack of training opportunities, lack of mobility opportunities, and an unconducive research environment). The R&D institutions (higher learning and research institutions) need to design and implement professional development programmes for early-career scientists to equip them with professional skills for their career development. Research programmes for young researchers and female researchers are essential for their career development. The government, through COSTECH, R&D institutions, and other research funding agencies, need to establish special funding programmes to support young scientists. Additionally, R&D institutions in Tanzania have to conduct regular training programmes in writing winning research proposals, research management, and other relevant training to equip young scientists.

Despite the country having a large number of scientific journals in which some of them are inactive, it was found that very few journals are indexed in the big and popular databases (WoS, Scopus and AJOL). This might lower the visibility and field strength of produced scientific knowledge in the country. It is recommended to accredit all scientific journals, which will be used for the promotion of researchers and academics in higher learning and research institutions. This will guarantee publications in genuine journals rather than predatory journals. Additionally, to minimise the cost of journal management, it is also recommended to merge small journals with large and active journals.

9.5 Limitations of the study

The research work is indicative of numerous areas for continued research. However, several limitations have been identified as explained below.

The bibliometric analysis method of the study identified Tanzanian researchers by assigning papers to affiliation institutions with Tanzanian addresses as reported by authors. In that scenario there could be some authors who published by using a foreign address, may have been omitted in the analysis. Additionally, there also could be some authors from foreign nationalities who are residing and working in Tanzania who were counted as Tanzanian scientists.

The survey section of the study analysed data from self-administered questionnaires with self-reporting responses, which could bring about under-reporting or over-reporting of some respondents. Additionally, there were too few respondents in the humanities scientific field to allow for statistical analysis. For that reason, that scientific field was omitted in the survey analysis.

The analysis of the Tanzanian human resources and GERD in this study used 2013 data, which is the latest data available from the UNESCO Institute of Statistics (UIS). The most recent available STI data in the UIS is up to 2013, while the most recent R&D survey was conducted in 2013. Therefore, between 2013 and 2020 the Tanzanian R&D personnel and GERD profiles could have changed.

9.6 Future research

As explained above, the bibliometric study of this research comprised only articles and reviews from the WoS. It is essential that future research should have a bibliometric analysis of articles and reviews from both local journals (which are not indexed in big databases) and scientific outputs from the popular databases to see the big picture of scientific production in the country. This will provide a comprehensive profile of publication outputs in all scientific fields, including the humanities and social sciences. Additionally, future research could include the analysis of the most top prolific authors across the scientific fields and the visibility of their publications.

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APPENDICES

Appendix 4.1: Survey questionnaire

Educational background

EDU.1 What is your highest qualification?

[ ] Doctoral or equivalent

[ ] Master or equivalent

[ ] Bachelor

[ ] Other (Specify)

EDU.2 When did you obtain your highest academic qualification?

Year [ ]

EDU.3 In which field did you obtain your highest qualification? (e.g. engineering, psychology, virology, agriculture etc.)

Open ended [specify field]

EDU.4 Was your highest qualification conferred by a university in one country?

[ ] Yes

[ ] No

EDU.5 [Only if EDU4=Yes] In which country did you obtain your highest qualification?

Country: [<dropdown list>]

EDU.6 [Only if EDU4=NO] In what countries did you obtain your highest qualification?

Country: [<dropdown list>]

Country: [<dropdown list>]

EDU.7 Are you currently enrolled in further postgraduate studies?

[ ] Yes

[ ] No

EDU.8 [Only if EDU5=Yes] At which institution and in which country?

[<open form.] – University

[<open form] – country

EDU.9 [Only if EDU7=yes]. Are your receiving a bursary or scholarship for your current studies?

[ ] Yes

[ ] No

Employment

EMP.1 Please specify the sector of employment of your current main job:

[ ] Higher/tertiary education [Explanation: university (public or private), college of technology, polytechnic and other institution providing tertiary education, or other institution directly under control of higher education institution]

[ ] Public research institution

[ ] Private research institution

[ ] Business enterprise

[ ] Non-governmental/non-profit organisation

[ ] Other Please specify: [< open form>]

EMP.2 What is your current employment status? If you hold more than one job, please answer for your main job.

[ ] Professor, Associate Professor or Reader at a Tertiary Institution

[ ] Senior lecturer at a Tertiary Institution

[ ] Lecturer or equivalent at a Tertiary Institution

[ ] Researcher/scientist

[ ] Postdoctoral fellow

[ ] Self-employed

[ ] Unemployed or inactive

[ ] Other Please specify: [< open form>]

EMP.3 [ONLY IF EMP2 ≠5,6,7] Is this position permanent or contract-based?

[ ] Permanent [Permanent employees are employed on an ongoing basis until the employer or the employee ends the employment relationship]

[ ] Contract-based [Contract employees are employed for a specific period of time or task, for example 6 to 12 months period, and employment ends on the date specified in the contract]

Working Conditions

WOR.1 On average, how many hours do you spend on your main job per week?

[ ] (maximum accepted: 100 hours)

WOR.2 In a typical year, what percentage of your working time do you spend on each of the following tasks?

[ ] % Undergraduate and Postgraduate teaching

[ ] % Training/supervising postgraduate students

[ ] % Research

[ ] % Administration and management

[ ] % Service (counselling of patients, voluntary services within or outside your organisation, article review, editorial duties)

[ ] % Consultancy

[ ] % Raising funds/grants for research

[ ] % Other, please specify [< open form>]

Research OutputRO.1 Please indicate how many of the following research output types you have produced over the last three years:

[Drop down: Options n/a,0-22;21+] Articles published/accepted (including co-authored) in refereed or peer reviewed academic journals

[Same options] Books (i.e. monographs and edited volumes)

[Same option] Book chapters (including co-authored)

[Same option] Conference papers published in proceedings

[Same option] Presentations at conferences to predominantly academic audiences

[Same option] Written input to official public policy documents

[Same option] Research reports (contract/consultation research)

[Same option] Articles in popular journals/magazines, essays, newspaper articles or other public outreach media

[Same option] Patents (applied for and/or granted)

[Same option] Computer programmes (including co-writing)

[Same option] Creative/artistic works of art performed or exhibited (e.g. music, sculpture, paintings, theatre, film)

[ ] Others, Please specify: [< open form with categories>] x3

RO.2 [Only if RO 1 CAT 1 ≠ 0] When did you publish your first research article in a refereed or peer-reviewed journal?

Year [ ]

RO.3 As far as your research is concerned, which of the following statements best describe the overall value or outcome of your research? Also rate the extent to which you believe that these have been successfully attained where applicable.

	Highly successful	Successful to some extent	Not successful at all	N/A
Advancement of knowledge	[ ]	[ ]	[ ]	
Solving of theoretical problems	[ ]	[ ]	[ ]	
Solving of immediate technical/applied problems	[ ]	[ ]	[ ]	

	Highly successful	Successful to some extent	Not successful at all	N/A
Solving of environmental or social problems	[ ]	[ ]	[ ]	
Development of skills and competencies	[ ]	[ ]	[ ]	
Change behaviour/attitudes/values	[ ]	[ ]	[ ]	
Influence policy/decision-makers	[ ]	[ ]	[ ]	
Influence practice	[ ]	[ ]	[ ]	
Stimulation of discussion/debate	[ ]	[ ]	[ ]	

RO.4 Please indicate which of the following stakeholders you consider when conceptualising your research:

[ ] Colleagues/scholars/peers in own discipline

[ ] Colleagues/scholars/peers in other discipline

[ ] The contracting agency

[ ] Industry/business/firm(s)

[ ] Ministry/government agency

[ ] Specific interest groups (e.g. farmers, researchers, nurses, doctors, consumers)

[ ] General public/society/community

Funding

FUN.1 Have you received any research funding over the past three years? (Excluding bursaries or scholarships for studying purposes)

[ ] No[ ] Yes - but I am not the primary recipient/grant holder of the funding

[ ] Yes- I am the primary recipient/grant holder of the funding

[ ] Yes – In some cases I am the primary recipient and in some cases I am not the primary recipient of the funding

FUN.2 [Only if FUN 1 =Yes] Approximately what percentage of this funding was for infrastructure and equipment? (Don't know, N/A, 0%,10% intervals)

[ ] %

FUN.3[Only if FUN 1 =Yes] What proportion of this funding was obtained from national and international sources? (10% intervals)

[ ] % National

[ ] % International

FUN.4 [Only if FUN 1 =Yes] Which amount best correspond to the total amount of research funding you have received during the past three years?

Dropdown list < Less than US$10 000; US$10 000 - 25 000; US$25 000 - 50 000; US$50 000 - 75 000;
US$75 000 - 100 000; US$100 000 - 250 000; US$250 000 - 500 000; US$500 000 - 1 000 000; More than US$ 1 000 000>

FUN.5 [Only if FUN 1 =Yes] Please specify the three organisations/agencies from which you have received the most funding over the past three years

[Specify] [< open form>]

[Specify] [< open form>]

[Specify] [< open form>]

Challenges

CHA.1 Indicate, where applicable, which of the factors listed below have impacted negatively on your career as an academic or scientist

	Not at all	To some extent	To a large extent
Lack of mentoring and support	[ ]	[ ]	[ ]
Job insecurity	[ ]	[ ]	[ ]
Balancing work and family demands	[ ]	[ ]	[ ]
Lack of mobility opportunities	[ ]	[ ]	[ ]
Lack of training opportunities to develop professional skills	[ ]	[ ]	[ ]
Lack of access to a library and/or information sources	[ ]	[ ]	[ ]

	Not at all	To some extent	To a large extent
Lack of research funding	[ ]	[ ]	[ ]
Lack of funding for research equipment	[ ]	[ ]	[ ]
Limitation of academic freedom	[ ]	[ ]	[ ]
Political instability or war	[ ]	[ ]	[ ]
Other, please specify	[ ]	[ ]	[ ]

International Mobility

MOB.1 In which country do you currently work/reside?

[<dropdown list>]

MOB.2 During the past three years, have you studied or worked in a country other than what you would consider your home country (i.e. abroad)?

[ ] Yes

[ ] No

MOB.3 [Only if MOB2 = Yes] Compared to the study/working conditions in your home country, how would you rate the study/working conditions abroad?

Researchers from:	Much worse abroad	Somewhat worse abroad	About the same	Somewhat better abroad	Much better abroad
Employment/job security	[ ]	[ ]	[ ]	[ ]	[ ]
Work-family balance	[ ]	[ ]	[ ]	[ ]	[ ]
Training opportunities	[ ]	[ ]	[ ]	[ ]	[ ]
Opportunities for research collaboration	[ ]	[ ]	[ ]	[ ]	[ ]
Research resources (personnel, scientific literature, material, etc.)	[ ]	[ ]	[ ]	[ ]	[ ]
Research funding opportunities	[ ]	[ ]	[ ]	[ ]	[ ]
Others, please specify [< open form>]	[ ]	[ ]	[ ]	[ ]	[ ]

MOB.4 [Only if MOB2 = Yes] How would you rate the importance of having studied/worked abroad for your career development?

[ ] Not important

[ ] Somewhat important

[ ] Important

[ ] Very important

[ ] Essential

MOB.5 Have you ever considered leaving the country where you currently work?

[ ] No, never

[ ] Yes, sometimes

[ ] Yes, often

MOB.6 [Only if MOB5 = Yes] List the main considerations for leaving the country:

<open ended form> x3

Collaboration

COL.1 How often do you collaborate, either in joint research or through joint publications, with the following categories of researchers:

	Never or very rarely	Rarely	Sometimes	Often	Very often/ always
Researchers at your own institution	[ ]	[ ]	[ ]	[ ]	[ ]
Researchers at other institutions in your own country	[ ]	[ ]	[ ]	[ ]	[ ]
Researchers at institutions in other African countries	[ ]	[ ]	[ ]	[ ]	[ ]
Researchers at institutions outside of Africa (e.g. Europe, North America, Asia, etc.)	[ ]	[ ]	[ ]	[ ]	[ ]

Mentoring

MO.1 During your career so far, have you ever received mentoring, support or training in the following:

	Never or very rarely	Yes but it was not valuable	Yes and it was valuable
Career decisions	[ ]	[ ]	[ ]

Introduction to research networks	[ ]	[ ]	[ ]
Attaining a position/job	[ ]	[ ]	[ ]
Research methodology	[ ]	[ ]	[ ]
Fundraising	[ ]	[ ]	[ ]
Scientific writing	[ ]	[ ]	[ ]
Presenting research results	[ ]	[ ]	[ ]

Demographic background

DEM.1 Are you:

[ ] Male

[ ] Female

DEM.2 What is your year of birth?

YEAR [ ] (yyyy)

DEM.3 What is your nationality?

Dropdown list [ ]

DEM.4 How many children or other dependents do you have?

Please enter a number in the relevant boxes.

[ ] Number of children/dependents aged 0 to 5

[ ] Number of children/dependents aged 6 to 18

[ ] Number of adult dependents aged 19 or older (including elderly)

[ ] I do not have any dependents.

DEM.5 How is the care-work and general housework for all dependents distributed in your family/relationship/household?

[ ]% me [ ]% partner [ ]% others (e.g. extended family, paid service)

4.2. Ethical Considerations

The study will use bibliometrics and the survey data. These data are not sensitive (has low risk) to require the ethical compliance. I understand the research ethics consideration when the human subjects are engaged. Therefore, we requested the ethical clearance to the Departmental Ethics Screening Committee (DESC) at CREST, Stellenbosch University as well as to the Tanzania Commission for Science and Technology (COSTECH).

UNITED REPUBLIC OF TANZANIA

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY (COSTECH)

TANZANIA COMMISSION FOR SCIENCE AND TECHOLOGY P.O. Box 4302 DAR-ES-SALAAM

RESEARCH PERMIT

Permit No.	2019–617- NA-2018- 401
Date	29th October 2019
Researcher's Name	Joseph William Maziku
Nationality	Tanzanian
Research Title	A Scientometric analysis of the Science System in Tanzania
Research Area(s)/Region(s)	Dar es Salaam
Validity	From:29th October 2019 to 28th October 2020
Local contact/collaborator *(with affiliated institution)*	Dr. William Joseph Kindeketa, Senior Research Officer, Tanzania Commission for Science and Technology (COSTECH), P.O. Box 4302, Dar es Salaam

Kindeketa

PROGRAM OFFICER

DIRECTOR GENERAL

IMPORTANT REQUIREMENTS

- *Research permit that involve collecting human, plant or animal materials / data that will be exported outside Tanzania must submit a signed Material Transfer Agreement (MTA), Data Transfer Agreement (DTA) between Tanzania host institution and the foreign counterpart. The MTA/DTA will indicate terms for collecting, storing/managing, transporting, disposal or returning of the materials/DATA to Tanzania after the closure of the research project.*
- *Any patent or intellectual property and royalty emanating from any research approved by the National Research Registration Committee (NRRC) shall be owned as stipulated in the research proposals and in accordance with the IP policy of the respective research institutions.*
- *All researchers are required to report to a Regional Administrative Secretary (RAS) of the study area and present the introduction letter and activity schedule(plan) prior starting any research activity.*
- *All researchers are required to submit quarterly progress reports and all relevant publications made after completion of the research.*
- *All communications should be addressed to COSTECH Director General through rclearance@costech.or.tz; dg@costech.or.tz or +255222700749; +255 (022) 2771358. Terms and conditions of the permit are found at www.costech.or.tz*

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NOTICE OF APPROVAL

REC: Social, Behavioural and Education Research (SBER) - Initial Application Form

26 March 2020

Project number: 14464

Project Title: A scientometric analysis of the science system in Tanzania

Dear Mr. Joseph Maziku

Your REC: Social, Behavioural and Education Research (SBER) - Initial Application Form submitted on 9 March 2020 was reviewed and approved by the REC: Social, Behavioural and Education Research (REC: SBE).

Please note the following for your approved submission:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
26 March 2020	25 March 2023

Ethics approval period:

GENERAL COMMENTS:

Permission has been granted by CREST to use their data sets and by the Tanzanian Commission on Science and Technology for permission to carry out the research. The study would be deemed to be a low risk study and qualified for ethics approval only on the grounds of 4.1.3 of the ethics application form which states that: *I am collaborating with an institution (or organisation or company) that is giving me access to physical data (or financial data) that is NOT linked to individuals or any personal accounts (or information).*

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: SBE, the researcher must notify the REC of these changes.

Please use your SU project number (14464) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

FOR CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

You are required to submit a progress report to the REC: SBE before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary).

Once you have completed your research, you are required to submit a final report to the REC: SBE for review.

Included Documents:

Document Type	File Name	Date	Version
Default	REC initial approval letter_SU-HSD-002130	14/04/2016	pdf
Proof of Ethics Clearance	REC initial approval letter_SU-HSD-002130	14/04/2016	pdf
Research Protocol/Proposal	Joseph PhD Proposal final 2018	13/02/2018	Final version
Budget	Tentative Budget2	11/03/2018	MS word
Default	Research Permit for Joseph Maziku-617	13/11/2019	Pdf
Investigator CV (PI)	CV	04/02/2020	MS word
Default	Joseph_permission for use of CREST data_27 November	06/03/2020	pdf

If you have any questions or need further help, please contact the REC office at

cgraham@sun.ac.za. Sincerely,

Clarissa Graham

REC Coordinator: Research Ethics Committee: Social, Behavioral and Education Research

National Health Research Ethics Committee (NHREC) registration number: REC-050411-032.

The Research Ethics Committee: Social, Behavioural and Education Research complies with the SA National Health Act No.61 2003 as it pertains to health research. In addition, this committee abides by the ethical norms and principles for research established by the Declaration of Helsinki (2013) and the Department of Health Guidelines for Ethical Research: Principles Structures and Processes (2nd Ed.) 2015. *Annually a number of projects may be selected randomly for an external audit.*

Principal Investigator Responsibilities

Protection of Human Research Participants

As soon as Research Ethics Committee approval is confirmed by the REC, the principal investigator (PI) is responsible for the following:

Conducting the Research: The PI is responsible for making sure that the research is conducted according to the REC-approved research protocol. The PI is jointly responsible for the conduct of co-investigators and any research staff involved with this research. The PI must ensure that the research is conducted according to the recognised standards of their research field/discipline and according to the principles and standards of ethical research and responsible research conduct.

Participant Enrolment: The PI may not recruit or enrol participants unless the protocol for recruitment is approved by the REC. Recruitment and data collection activities must cease after the expiration date of REC approval. All recruitment materials must be approved by the REC prior to their use.

Informed Consent: The PI is responsible for obtaining and documenting affirmative informed consent using **only** the REC-approved consent documents/process, and for ensuring that no participants are involved in research prior to obtaining their affirmative informed consent. The PI must give all participants copies of the signed informed consent documents, where required. The PI must keep the originals in a secured, REC-approved location for at least five (5) years after the research is complete.

Continuing Review: The REC must review and approve all REC-approved research proposals at intervals appropriate to the degree of risk but not less than once per year. There is **no grace period.** Prior to the date on which the REC approval of the research expires, **it is the PI's responsibility to submit the progress report in a timely fashion to ensure a lapse in REC approval does not occur.** Once REC approval of your research lapses, all research activities must cease, and contact must be made with the REC immediately.

Amendments and Changes: Any planned changes to any aspect of the research (such as research design, procedures, participant population, informed consent document, instruments, surveys or recruiting material, etc.), must be submitted to the REC for review and approval before implementation. Amendments may not be initiated without first obtaining written REC approval. The **only exception** is when it is necessary to eliminate apparent immediate hazards to participants and the REC should be immediately informed of this necessity.

Adverse or Unanticipated Events: Any serious adverse events, participant complaints, and all unanticipated problems that involve risks to participants or others, as well as any research-related injuries, occurring at this institution or at other performance sites must be reported to the REC within **five (5) days** of discovery of the incident. The PI must also report any instances of serious or continuing problems, or non-compliance with the RECs requirements for protecting human research participants.

Research Record Keeping: The PI must keep the following research-related records, at a minimum, in a secure location for a minimum of five years: the REC approved research proposal and all amendments; all informed consent documents; recruiting materials; continuing review reports; adverse or unanticipated events; and all correspondence and approvals from the REC.

Provision of Counselling or emergency support: When a dedicated counsellor or a psychologist provides support to a participant without prior REC review and approval, to the extent permitted by law, such activities will not be recognised as research nor the data used in support of research. Such cases should be indicated in the progress report or final report.

Final reports: When the research is completed (no further participant enrolment, interactions or interventions), the PI must submit a Final Report to the REC to close the study.

On-Site Evaluations, Inspections, or Audits: If the researcher is notified that the research will be reviewed or audited by the sponsor or any other external agency or any internal group, the PI must inform the REC immediately of the impending audit/evaluation.

Appendix 6.1 International Classification on Education (ISCED)

Researchers by formal qualification : Adapted from OECD (2015), Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development

Researchers by formal qualification : Professionals engaged in the conception or creation of new knowledge (who conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods) broken down by their formal level of qualification (ISCED level 8, ISCED level 7, ISCED level 6, ISCED level 5, or all lower ISCED levels combined).

Headcount (HC) of R&D personnel: The headcount (HC) of R&D personnel is defined as the total number of individuals contributing to intramural R&D, at the level of a statistical unit or at an aggregate level, during a specific reference period (usually a calendar year). That means headcount data reflect the total number of persons who are mainly or partially employed in R&D. The use of HCs is mostly recommended in terms of exploring, usually in percentage terms, the characteristics of R&D personnel.

Level of formal qualification (for R&D data): The International Standard Classification of Education (ISCED) provides the basis for classifying R&D personnel by formal qualification. Five classes are recommended for the purposes of R&D statistics. They are defined exclusively by level of education, regardless of the field in which personnel are qualified.

• ISCED 8: Doctoral or equivalent level: Programmes at ISCED level 8, or doctoral or equivalent level, are designed primarily to lead to an advanced research qualification. Programmes at this ISCED level are devoted to advanced study and original research and are typically offered only by research-oriented tertiary educational institutions such as universities. Doctoral programmes exist in both academic and professional fields.

• ISCED 7: Master's or equivalent level: Programmes at ISCED level 7, or Master's or equivalent level, are often designed to provide participants with advanced academic and/or professional knowledge, skills and competencies, leading to a second degree or equivalent qualification.

Programmes at this level may have a substantial research component but do not yet lead to the award of a doctoral qualification. Typically, programmes at this level are theoretically-based but may include practical components and are informed by state of the art research and/or best professional practice. They are traditionally offered by universities and other tertiary educational institutions.

• ISCED 6: Bachelor's or equivalent level: Programmes at ISCED level 6, or Bachelor's or equivalent level, are often designed to provide participants with intermediate academic and/or professional knowledge, skills and competencies, leading to a first degree or equivalent qualification. Programmes at this level are typically theoretically-based but may include practical components and are informed by state of the art research and/or best professional practice. They are traditionally offered by universities and equivalent tertiary educational institutions. First degree programmes at this level typically have a duration of three to four years of full-time study at the tertiary level.

• ISCED 5: Short-cycle tertiary education: Programmes at ISCED level 5, or short-cycle tertiary education, are often designed to provide participants with professional knowledge, skills and competencies. Typically, they are practically based, occupationally-specific and prepare students to enter the labour market. However, these programmes may also provide a pathway to other tertiary education programmes. Academic tertiary education programmes below the level of a Bachelor's programme or equivalent are also classified as ISCED level 5.

• ISCED 4 or below: This includes ISCED 4 (post-secondary non-tertiary education), ISCED 3 (upper secondary education) and below. ISCED 4: Post-secondary non-tertiary education: Post-secondary non-tertiary education provides learning and educational activities building on secondary education preparing for both labour market entry as well as tertiary education. It typically targets students who have completed upper secondary (ISCED level 3) but who want to increase their opportunities either to enter the labour market or to progress to tertiary education. Programmes are often not significantly more advanced than those at upper secondary as they typically serve to broaden rather than deepen knowledge, skills and competencies. It therefore aims at learning below the high level of complexity characteristic of tertiary education. ISCED 3: Upper secondary education: Programmes at ISCED level 3, or 'upper secondary' education, are typically designed to complete secondary education in preparation for tertiary education, or to provide skills relevant to employment, or both. Programmes at this level offer students more varied, specialised and in-depth instruction than programmes at lower secondary education (ISCED level 2). They are more differentiated, with an increased range of options and streams available (OECD ,2015).

Appendix 8.1: Tanzanian publication collaboration profiles across scientific fields from 2005 to 2018

Publication year	% Single author	% National collaboration	% Collaboration with African countries	% Collaboration with countries outside Africa
2005	8,21	7,90	3,04	82,37
2006	6,18	11,40	6,18	77,67
2007	7,37	9,82	5,36	79,24
2008	6,30	9,35	4,13	81,52
2009	7,33	11,54	6,41	75,64
2010	6,29	10,12	5,21	79,14
2011	8,13	11,41	6,56	75,61
2012	4,51	9,01	5,07	82,25
2013	4,26	9,78	5,64	80,67
2014	5,82	8,91	6,47	79,55
2015	4,55	11,05	5,88	79,14
2016	4,95	9,15	6,30	80,35
2017	4,45	9,84	7,19	79,14
2018	3,46	11,52	6,55	79,05
Average	**5,84**	**10,06**	**5,01**	**79,38**

Appendix 8.2: Tanzanian publication collaboration profiles for health sciences

Publication year	% Single author	% National collaboration	% Collaboration with African countries	% Collaboration with countries outside Africa
2005	2,380952	4,166667	2,380952	92,2619
2006	2,242152	9,865471	3,139013	85,20179
2007	3,375527	9,2827	1,265823	87,34177
2008	1,181102	6,692913	3,149606	89,37008
2009	1,365188	9,897611	3,754266	84,98294
2010	1,404494	8,426966	3,089888	87,35955
2011	1,507538	12,0603	3,266332	83,9196

2012	0,496278	10,91811	4,466501	84,11911
2013	1,041667	9,791667	4,166667	85,20833
2014	1,476015	8,856089	4,428044	85,42435
2015	2,101576	13,13485	2,977233	82,31173
2016	1,351351	10,81081	2,195946	85,97973
2017	0,46875	10,15625	4,21875	85,15625
2018	0,440529	9,985316	3,524229	86,19677
Average	**1,43808**	**9,574695**	**3,287375**	**86,05957**

Appendix 8.3: Tanzanian publication collaboration profiles for agricultural sciences

Publication year	% Single author	% National collaboration	% Collaboration with African countries	% Collaboration with countries outside Africa
2005	0	20	3,333333	76,66667
2006	1,315789	14,47368	11,84211	72,36842
2007	2,666667	8	13,33333	76
2008	0	18,64407	13,55932	67,79661
2009	6,451613	19,35484	16,12903	58,06452
2010	4,477612	22,38806	8,955224	64,1791
2011	2,739726	17,80822	16,43836	63,0137
2012	3,225806	14,51613	4,83871	77,41935
2013	0	15,625	21,875	62,5
2014	2,654867	16,81416	9,734513	71,68142
2015	1,709402	7,692308	11,11111	79,48718
2016	0,757576	8,333333	15,90909	75
2017	2,173913	8,695652	15,21739	74,63768
2018	1,257862	10,06289	22,01258	67,2956
Average	**2,102202**	**14,45774**	**13,16351**	**70,43645**

Appendix 8.4: Tanzanian publication collaboration profiles for social sciences

Publication year	% Single author	% National collaboration	% Collaboration with African countries	% Collaboration with countries outside Africa
2005	27,58621	8,62069	5,172414	63,7931
2006	20,89552	13,43284	4,477612	65,67164
2007	12,90323	4,83871	8,064516	74,19355
2008	16,21622	4,054054	8,108108	72,97297
2009	13,72549	9,803922	7,843137	71,56863
2010	16,91176	6,617647	4,411765	72,79412

2011	27,43363	9,734513	8,849558	56,63717
2012	15,74803	7,086614	6,299213	73,22835
2013	15	12,85714	6,428571	66,42857
2014	17,64706	5,347594	3,208556	75,93583
2015	11,97917	11,97917	4,6875	72,91667
2016	14,07767	7,76699	10,67961	69,90291
2017	12,19512	10,1626	7,723577	71,54472
2018	12,11073	9,342561	5,882353	75,08651
Average	**16,74499**	**8,688931**	**6,559749**	**70,19105**

Appendix 8.5 :Tanzanian publication collaboration profiles for natural sciences

Publication year	% Single author	% National collaboration	% Collaboration with African countries	% Collaboration with countries outside Africa
2005	7,058824	4,705882	4,705882	85,88235
2006	3,418803	11,96581	9,401709	76,92308
2007	8,888889	10,37037	8,148148	74,07407
2008	8,163265	14,28571	2,721088	77,55102
2009	8,695652	9,937888	6,21118	75,15528
2010	3,763441	10,21505	5,913978	81,1828
2011	7,425743	7,920792	5,445545	80,69307
2012	3,589744	4,102564	5,128205	87,17949
2013	0,763359	5,725191	4,198473	89,31298
2014	1,52439	5,487805	9,756098	83,53659
2015	2,259887	6,779661	5,932203	85,02825
2016	4,123711	7,474227	5,154639	84,02062
2017	2,133333	6,666667	6,4	84,8
2018	0,691244	11,05991	4,37788	84,3318
Average	**4,464306**	**8,335538**	**5,963931**	**82,11938**

Appendix 8.6 :Tanzanian publication collaboration profiles for engineering & applied technologies

Publication year	% Single author	% National collaboration	% Collaboration with African countries	% Collaboration with countries outside Africa
2005	25	8,333333	0	75
2006	11,76471	29,41176	0	58,82353
2007	8,333333	8,333333	0	83,33333

2008	28,57143	14,28571	0	57,14286
2009	4	8	4	84
2010	5,555556	16,66667	27,77778	50
2011	18,75	12,5	6,25	62,5
2012	6,896552	6,896552	6,896552	79,31034
2013	4,878049	7,317073	12,19512	75,60976
2014	4,081633	8,163265	8,163265	81,63265
2015	6,349206	6,349206	20,63492	66,66667
2016	6	4	18	72
2017	6,25	12,5	12,5	68,75
2018	3,448276	18,96552	8,62069	68,96552
	9,991338	**11,5516**	**8,931309**	**70,26676**

Appendix 8.7: **Tanzanian publication collaboration profiles for humanities**

Publication year	**% Single author**	**% National collaboration**	**% Collaboration with African countries**	**% Collaboration with countries outside Africa**
2005	50	16,66667	0	33,33333
2006	40	0	20	40
2007	80	0	0	50
2008	42,85714	14,28571	14,28571	28,57143
2009	38,46154	7,692308	13,38462	53,84615
2010	45,45455	0	9,090909	54,54545
2011	64,28571	0	14,28571	50
2012	50	0	10	70
2013	58,82353	5,882353	0	38,05882
2014	68,18182	4,545455	0	36,36364
2015	47,61905	0	14,28571	52,38095
2016	45,45455	0	4,545455	54,54545
2017	52	4	20	36
2018	39,13043	17,3913	8,695652	39,13043
Average	**51,39059**	**5,033129**	**7,326698**	**37,12683**