

Biotechnology and Bioentrepreneurship in Tanzania

IHI_UNESCO Survey & Stakeholders Meeting Report 2011



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Executive Summary

This report on Biotechnology and Bioentrepreneurship in Tanzania, commissioned by the UNESCO to the Ifakara Health Institute, aims to provide as clear a picture of the challenges faced by policy-makers and stakeholders to take science from the lab to the market. During recent years, a number of national and international reports have provided critical insight into the gaps in the Tanzanian innovation framework. Moreover, the Ministry of Communications, Science and Technology has recently published in December 2010, two key national policy papers on Research and Development and Biotechnology respectively.

Based on the existing body of information collected this report since its inception aimed, with the approval of the UNESCO, to go beyond its strict “reporting” framework in order to catalyze the first steps from policy to implementation. It is articulated into two main parts, one based on a survey carried out in November 2010 and February 2011 in 22 selected sites across the biotechnology value chain with more than 40 interviews across Tanzania. The survey’s findings are complemented by the organization of an encounter between representative national stakeholders to identify jointly with the private sector the obstacles to the effective uptake and commercialisation of biotechnology-based products. This one-day meeting, one of the first of its kind, brought together key representatives from the government, academic research institutions, private biotechnology-based companies and international ST&I experts to discuss the commercialisation of biotechnology and bioentrepreneurship. The report outcomes, based on the information collected during the survey and the discussions generated between stakeholders at the meeting, are synthesized in a list of recommendations that address the first steps that need to be taken for policy implementation. This first one-day encounter, in addition to its immediate output and recommendations, underscored the urgent need to promote more frequent interactions between national ST&I stakeholders and sustainable links with the private sector.

Acknowledgements

This report is written thanks to the time and patience of all those who kindly agreed to participate despite very busy schedules. Thanks to Kefas Mugittu who provided expert knowledge of the Tanzanian ST&I institutions and players. Lucy Hoareau from the UNESCO Biotechnology Division is warmly thanked for her expert guidance as well as Yoslan Nur and Folarin Osotimehin for their time and advice. Interviewees in Tanzania thanks to whom this report was possible, listed by order of meeting, are thanked for their insightful comments and guidance: P.S. Gwakisa, E. I. Mbede, R.T. Chibunda, H. Mshinda, R. R. Kingamkono, N. Nyange, G.S. Shemdoe, E.M. Achayo, P.B. Marwa, J.A. Lyatuu, F. Roman, C.V. Lyimo, B. Lyimo, H.B. Sillo, R. Wigenge, A.M. Khea, H.M. Malebo, E. Kullaya, Q. Mgani, G. Mtui, E. Mneney, R. Sallu, B. Muamila, E.E. Kimaro, E.F.A. Njau, C. Lyamchai, S. Kweka, I. Mamuya, J. Senbosi, L.C. Manege, M. Ndosu, Z.H. Mbwambo, J.J. Magadula, D.L. Kilambo, G. Kibiki, F. Moshu, R. Kavishe, S. Abdulla, G. Killeen and H. Upreti.

Special thanks to the panel of international and national experts and stakeholders for providing invaluable insight in strengthening the commercialisation of biotechnology in Tanzania: A.Daar, P. Gwakisa, K. Hosea, J. Makani, W. Marandu, G. Mergui, H. Mshinda, J. Mugini, C. A. Ngeleja, A.Olckers, K. Plate, W.Ronoh, J. Shamte, K. Simuyu, P. Singer and N. Temu.

The author also thanks the panel of international experts for critical reading of the report.

List of Abbreviations and Acronyms

AMCOST	African Ministerial Council on Science and Technology
AU	African Union
BAC	Biotechnology Advisory Centre
BRELA	Business Registrations and Licensing Agency
CAMARTEC	Centre for Agriculture and Mechanization Rural Technology
CASS	College of Arts and Social Sciences
COSTECH	Commission of Science and Technology
CVL	Central Veterinary Laboratory
DAF	Directorate Administration and Finance
DCDTT	Directorate Centre for the Development and Transfer of Technology
DID	Directorate of Information and Documentation
DFI	Direct Foreign Investment
DRCP	Directorate of Research Coordination and Promotion
DRT	Department of Research and Training
EAC	East African Community
EAHC	East African High Commission
EDS	Export Development Strategy
ESRF	Economic and Social Research Foundation
GDP	Gross Domestic Product
GMO	Genetically Modified Organisms
HDI	Human Development Index
HR	Human Resources
ICGEB	International Centre for Genetic Engineering and Biotechnology
ICT	Information Communication Technology
IHI	Ifakara Health Institute
IMF	International Monetary Fund
IPR	Intellectual Property Rights
KCMC	Kilimanjaro Christian Medical Centre
MARI	Mikocheni Agriculture Research Institute
MCST	Ministry of Communication, Science and Technology
MITM	Ministry of Industry, Trade and Marketing
MUHAS	Muhimbili University of Health and Allied Sciences
MKUKUTA	Mkakati wa Kukuza Uchumi na Kuonda Umaskini (see NSGPR)
MSD	Medical Stores Department
NEMC	National Environment Management Council
NEPAD	New Partnership for Africa's Development

NGO	Non-Governmental Organization
NHBRA	National Housing and Building Research Agency
NIMR	National Institute for Medical Research
NMU	Nelson Mandela University
NSGPR	National Strategy for Growth and Poverty Reduction
OECD	Organisation for Economic Co-operation and Development
PoC	Proof of Concept
R&D	Research and Development
RSA	Republic of South Africa
SADC	South African Development Community
SARI	Selian Agriculture Research Institute
SIDO	Small Scale Industries Development Organization
SIDP	Sustainable Industrial Development Policy
SME	Small and Medium-sized Enterprises
S & T	Science and Technology
S, T & I	Science, Technology and Innovation
SUA	Sokoine University of Agriculture
SWOT	Strengths, Weaknesses, Opportunities, Threats
TAFIRI	Tanzania Fisheries Research Institute
TAFORI	Tanzania Forestry Research Institute
TAWIRI	Tanzania Wildlife Research Institute
TBS	Tanzanian Bureau of Standards
TC	Telecommunication
TDTC	Technology Development and Transfer Centre
TEMDO	Tanzania Engineering and Manufacturing Design Organization
TIPASIC	Tanzanian Intellectual property advisory services and information centre
TIRDO	Tanzania Industrial Research and Development Organization
TPRI	Tanzania Pesticide Research Institute
TRIPS	Trade-related aspects of Intellectual Property Rights
TT	Technology Transfer
TTIS	Tanzania Trade Integration Strategy
UDSM	University of Dar es Salaam
UNDP	United Nations Development Program
VC	Venture Capital
WB	World Bank
WEF	World Economic Forum
WEMA	Water Efficient Maize for Africa

Table of Contents

INTRODUCTION	9
1. Biotechnology and bioeconomy	10
1.1 Definitions.....	10
1.2 The Biotechnology value chain.....	11
2. Tanzania	11
2.1 Overview	11
2.1.1 S&T critical mass and output	12
2.1.2 Women in S&T	13
2.2 National policy milestones.....	15
2.3 The National Biotechnology Policy	16
2.4 Interplay of technology transfer systems in place.....	18
3. Survey	18
3.1 Methods.....	18
3.2 Interviews	19
3.3 Findings.....	20
3.3.1 Governance, coordination and policy implementation	20
3.3.2 From Research to Proof of Concept	21
3.3.2.1 Funding	21
3.3.2.2 Training	22
3.3.2.3 Technology platforms and transfer support structures	22
3.3.3 Beyond Proof of Concept.....	22
3.3.4 Sustainable up scaling.....	23
3.3.5 Preliminary list of biotechnology-based products and services in the pipeline.....	24
3.3.6 Potential for domestic substitution of imported products	25
3.3.7 SWOT analysis of the Tanzanian biotechnology value chain	25
4. Stakeholders Meeting	25
4.1 Rationale.....	25
4.2 Discussion Summary	26
4.2.1 Part 1 International Experts	26
4.2.2 Part 2 National Stakeholders & International Experts.....	30
4.3 Recommendations.....	35
5. Conclusions.....	37
6. References.....	38
7. Annexes	39
1. Preliminary list of visits and questionnaire	40
2. List of interviewees and affiliation	40
3. COSTECH and affiliated R&D committees.....	42
4. Biosketches of international experts	42

List of Figures

- 1 *Institutionalizing Technological Change through Technology Transfer Pillars, AMCOST 20 – 24 NOVEMBER 2006, Cairo, Egypt*
- 2 *Biotechnology and economic development*
- 3 *The biotechnology value chain from bench to business*
- 4 *World Bank Knowledge Indexes of Tanzania, Kenya, Botswana and South Africa*
- 5 *Summary of National Policies' framework related to the promotion and commercialisation of Science & Technology-based products*
- 6 *Summary of main National Biotechnology Policy priorities 2010*
- 7 *Tanzania S&T stakeholders*
- 8 *COSTECH and the implementation of S&T policy*
- 9 *Tanzania interplay of existing technology transfer structures*
- 10 *Biotechnology Framework*
- 11 *SWOT analysis of Tanzania's biotechnology value chain*

List of Tables

- 1 *Tanzania basic economic indicators*
- 2 *Tanzania research output 1990-2011*
- 3 *Enrolment in government and non-government universities and university colleges, 2009-2010*
- 4 *Higher Education students studying abroad by cultural scholarships by field of study 2009-2010*
- 5 *List of institutions visited*
- 6 *Potential demand-driven fields of application of biotechnology*
- 7 *Preliminary list of biotechnology-based products and services and stage of development*

INTRODUCTION

Biotechnology is defined as the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services¹. A more practical definition is “the use of cellular and biomolecular processes to solve problems or make useful products.”² Biotechnologies in plural would therefore reflect best the “collection of technologies that capitalize on the attributes of cells, such as their manufacturing capabilities, and put biological molecules, such as DNA and proteins, to work for us”.

Biotechnologies have shown significant potential in an increasing number of economic sectors by delivering products that address draught, famine and malnutrition, improve human and animal health and reduce the environmental impact of industrial activities leading to improved quality of life and sustainable economic growth.

These advances address a number of challenges faced by African countries. The potential to benefit from biotechnologies depends on the convergence of development policies and governance structures with the capacity for technological innovation. During the past decades, science, technology and innovation have been moving to the centre stage of African development strategies and the focus of regional economic integration and trade. High-level decisions to promote the “freedom to innovate”³ in science and technology have been taken since the first AMCOST meetings in 1987 to the 2007 report by the High Level African Panel on Modern Biotechnology of the African Union (AU) and the New Partnership for Africa’s Development (NEPAD).

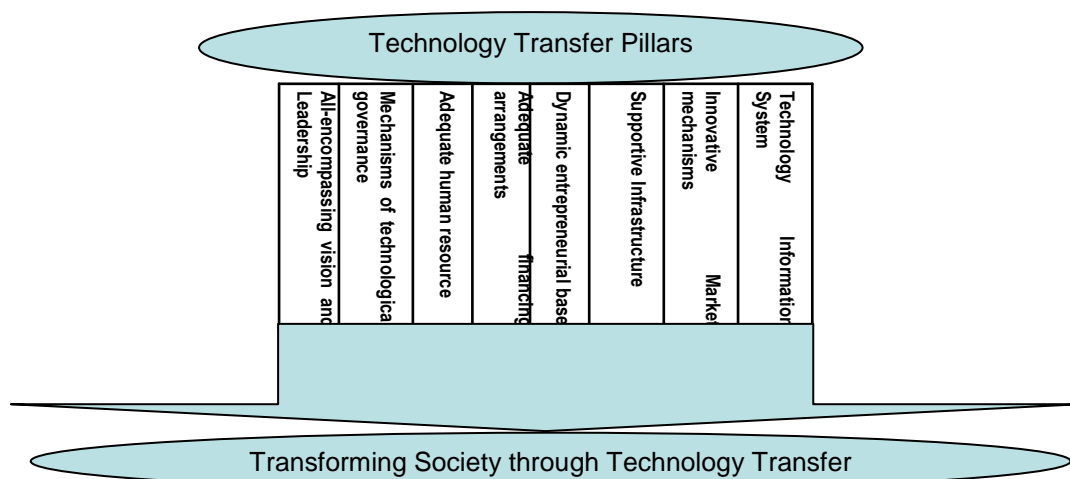


Figure 1. Institutionalizing Technological Change through Technology Transfer Pillars
AMCOST 20 – 24 NOVEMBER 2006, Cairo, Egypt

The move beyond policy towards the implementation of these decisions at regional, national and local level remains a key challenge. Profound changes in academic mindsets, prioritization of

¹ OECD, 2001

² The Biotech Guide, The Biotechnology Industry Organization, 2008

³ Juma, C. and Serageldin I., Freedom to innovate: Biotechnology in Africa’s Development. Addis Ababa: African Union and New Partnership for Africa’s Development, 2007

University-Industry-Government linkages, associated incentives and funding schemes as well as infrastructure development need to be considered. Stakeholders shall need to evaluate these steps to address the innovation bottlenecks at national and regional levels.

This report has been commissioned by the UNESCO on Biotechnology and Bioentrepreneurship in Tanzania. It is based on a survey carried out in November 2010 and February 2011 in 22 sites across the biotechnology value chain with more than 40 interviews across Tanzania. The survey's findings are complemented by recommendations from an international panel of experts and national stakeholders to strengthen the uptake of biotechnology and bioentrepreneurship following a one-day meeting in Dar es Salaam.

1. Biotechnology and bioeconomy

1.1 Definitions

First generation or traditional biotechnology has been a part of human history since the use of yeast and bacteria for food processing and selective animal breeding. Second generation biotechnology includes the use of biological-based mechanisms in food processing, alcohol production, dairy production and bioprocessing to make biopharmaceuticals and fine chemicals. The discovery of the DNA molecule and the advent of DNA recombinant technology led to the development of third generation biotechnology which now also interfaces with nanotechnology and material sciences. Third generation techniques may be combined with first, second or third generation core processes.

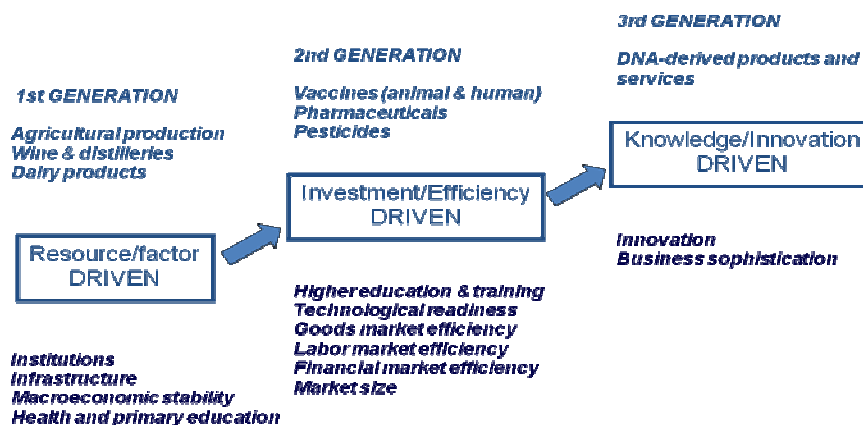


Figure 2. Biotechnology and economic development

Biotechnologies can also be classified according to their field of application. Green biotechnology refers to techniques applied to agriculture such as tissue culture, marker-aided selection and genetic engineering technology. Biotechnology applied to human and animal health including vaccines, gene therapy and medical devices is referred to as red biotechnology. White biotechnology or industrial biotechnology refers to the production of chemicals and derived biomaterials such as biofuels, with additional applications in mining and resource extraction.

The application of biotechnology to agriculture, health and industry can contribute significantly to economic development and growth. According to the OECD⁴, several factors may drive the emerging bioeconomy by creating opportunities for investment. In developing countries, increasing population and per capita income as well as the use of biotechnology to meet the challenge of environmentally sustainable production are all major drivers. This trend indicates that developing countries could be the main markets for biotechnology in primary production (agriculture, forestry and fishing). In addition, the increase in energy demand, when combined with measures to reduce greenhouse gases, could also create large markets for biofuels.

A sustainable bioeconomy is an ensemble of elements. Life sciences alone cannot contribute to development. The skills and resources required to carry out scalable biotechnology-based research and development depend on factors of increasing complexity and interconnection. Linkage between University, Industry and Government has been identified as a key element to jumpstart the process taking advantage of the global existing body of knowledge and know-how. Technological and logistics infrastructure, communication and energy development programs also require supporting policies and execution thereof. The state must take a leading role in the establishment and the maintenance of a truly enabling environment, the promotion of social acceptance and the development of key economic infrastructure and services in partnership with the private sector.

1.2 The Biotechnology Value chain

The value chain model is used in this report in order to analyse the innovation system from the start point at higher education centres where scientists are trained to the biotechnology-based product presented to the market taking into account the framework conditions necessary to support science-based innovation. These include a strong science base with excellent universities and technology platforms, binding government policy, public and private long-term financial investment as well as technology transfer and intellectual property rights agents. The steps from research to product will be analyzed in the following survey using this model in order to identify gaps.



Figure 3. The biotechnology value chain from bench to business

2. Tanzania

2.1 Overview

⁴ The Bioeconomy to 2030, Designing a policy Agenda, OECD, 2009

The United Republic of Tanzania was constituted by the union of Tanganyika and Zanzibar in 1964. Since independence in 1961 until the mid-80's, Tanzania followed a socialist model of economic development followed from the early 90's by a multiparty parliamentary democracy. An economic adjustment program supported by the World Bank, the International Monetary Fund and bilateral donors aiming to reduce state economic controls and promote private sector participation has contributed to an average overall GDP rate of 6% a year over the last decade.

Agriculture is the mainstay of the economy accounting for 45 percent of the GDP. This sector also accounts for two thirds of merchandise exports and employs 80 percent of the labour force. The manufacturing sector is still underdeveloped while services characterized mainly by public administration, tourism and financial services. Tanzania remains one of the world's least developed countries ranking 148 out of 169 countries in the UNDP Human Development Index in 2010.

Basic economic indicators are summarized in the following table⁵:

Population (millions, 2009):	43,7
Area (sq km):	947 000
GDP (US \$ billions, 2009):	22,3
GDP per capita (US \$, 2009):	550,5
<i>Sectorial value-added (% of GDP, 2006):</i>	
<i>Agriculture</i>	45,3
<i>Industry</i>	17,4
<i>Services</i>	37,3
Human Development Index, 2010	Score (0-1, 1 is best) 0,4
	Rank (out of 169 economies) 148

Table 1. Tanzania basic economic indicators

Tanzania benefits from political stability since independence, high donor funding and positive GDP growth, which are slowly translating in improved education, innovation and ICT indicators⁶:

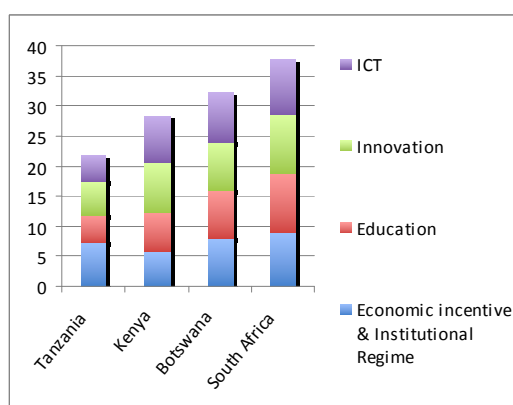


Figure 4. World Bank Knowledge Indexes of Tanzania, Kenya, Botswana and South Africa

2.1.1 Science and Technology critical mass and output

⁵ The Africa Competitiveness Report 2011, World Economic Forum, the World Bank and the African Development Bank

⁶ Knowledge Economy Index, Knowledge Assessment Tool, World Bank, 2009

The current R&D expenditure as share of GDP is 0,18%⁷ despite a pledge for increase to 1% in 2007. Tanzania has a high number of research institutions, approximately 44 to date⁸, many of which date back to the early 20th century⁹.

Research output in peer-reviewed journals is steadily increasing as shown in the table¹⁰ below and places Tanzania in second position among SADC countries after South Africa.¹¹ Nevertheless this high scientific production is not reflected in the number of patents registered⁶.

1990-1995	1995-2000	2000-2005	2005-2011
1076	1321	1607	2688

Table 2. Tanzania Research Output 1990-2011

2.1.2 Women in Science and Technology

In developing countries even more than in developed countries, women's role is central for the provision of food, energy, family economy, healthcare and education. Conversely this same burden of responsibility hinders their representation at decision-making levels much more.

Tanzania has adopted the Beijing Declaration and Platform for action on the access of women to education, training and employment as priority areas for implementation. The Ministry of Community Development, Gender and Children was established in 1990 to spearhead gender development in the country. The Women and Gender Development Policy (2000) ensures that the gender perspective is mainstreamed into all policies, programmes and strategies with the establishment of gender focal points in ministries, independent government departments, regional and local authorities. A National Strategy for Gender Development (NSGD) was also put in place in 2005.

Nevertheless Higher Education Statistics show that despite a three-fold increase in enrolment in Universities and University colleges from 2006 to 2009¹² the percentage of women remains limited to approximately 30%. According to the report by Dr. Kingamkono¹³, this divergence increases even more in higher education and policy-making positions.

Nurturing women in Science, Technology and Innovation and preventing leaks in the pipeline need to be addressed at several levels: already at primary and secondary school to "demystify

⁷ Personal communication Dr. E. Mbede, Director of Research, Ministry of Communication, Science and Technology of Tanzania

⁸ Madikizela, M., Mapping Research Systems in Developing Countries, *Country Report: The Science and Technology System of Tanzania*, Centre for Research on Science and Technology (CREST), University of Stellenbosch, South Africa and Institute for Research and Development, France, published with the support of the UNESCO, 2007

⁹ Kingamkono, R.R. and Mshinda, H., Current Status of S&T in Tanzania, Workshop on Capacity Development in Health Research, Arusha 9-10 March, 2009

¹⁰ NCBI PubMed database, February 2011

¹¹ South African Regional Universities Association (SARUA), The state of public Science in SADC, produced by Centre for Research on Science and Technology, University of Stellenbosch, South Africa, 2008

¹² Basic Education Statistics in Tanzania (BEST), 2006-2010 Revised National Data, Dar es Salaam, Ministry of Education and Vocational Training, September 2010

¹³ Kingamkono, R.R., Gender, Science and Technology in Tanzania: A situation Analysis, Scientific and Technology Conference, 24-26 May 2006

science”, promotion at higher education institutions beyond graduate levels and upon employment with favourable policies to counter family barriers.

The tables below show the distribution of male and female students in Higher Education Institutions as well as the gender parity index (GPI) in 2009-2010:

Table 3. Enrolment in Government and Non-Government Universities and University Colleges, 2009-2010

Type of Institution	Undergrad			Master's			PhD			TOTAL <i>Including post grad</i>			GPI
	M	F	T	M	F	T	M	F	T	M	F	T	
Government	42195	21270	63465	6017	2463	8480	311	109	420	56054	27774	83828	0,33
Non-Government	19601	13172	32773	382	146	528	16	6	22	20881	14242	35123	0,40
TOTAL	61796	34442	96238	6399	2609	9008	327	115	442	76935	42016	118951	0,35
GPI	0,35			0,28			0,26			0,35			

2009-2010	M	F	TOTAL
Male and Female %	64,7	35,3	100
Enrolment in Technical College	29680	20493	50173
Total Tertiary Enrolment (Higher & Technical)	106615	62509	169124
Population 20-23 years	1599966	1594390	3194356
Gross Enrolment Ratio (GER)	6,7	3,9	5,3

Table 4. Higher Education Students studying abroad by cultural scholarships by field of study 2009-2010

Field	Undergrad			Master's			PhD			TOTAL			GPI
	M	F	T	M	F	T	M	F	T	M	F	T	
Agriculture, Natural Resource and Environment	25	9	34	4	2	6	0	0	0	29	11	40	0,4
Business and Management	52	20	72	0	0	0	1	0	1	53	20	73	0,4
Engineering and other Sciences	151	25	176	25	3	28	2	0	2	178	28	206	0,2
Health and Allied Sciences	76	37	113	17	3	20	2	0	2	95	40	135	0,4
Planning and Welfare	2		2	0	0	0	0	0	0	2	0	2	0,0
Social Sciences	26	14	40	0	0	0	0	0	0	26	14	40	0,5
Education	3	5	8	4	1	5	0	0	0	7	6	13	0,9
TOTAL	335	110	445	50	9	59	5	0	5	390	119	509	0,3

The implementation of gender mainstreaming policies should be based on the recognition of women as integral to sustainable development. During the survey interviews, in addition to the economy, both culture and education emerged as key factors that were being addressed through outreach programs specifically for girls to promote science at primary and secondary school levels. COSTECH plans to organize a Science Week where students can be exposed to both male and

female scientists and the economic relevance of science-related projects. Moreover a Science Museum Project is also in the pipeline¹⁴.

The important role of NGOs was also underscored in giving support to girl students (Female Association Of Women’s Education) or advocating women’s empowerment (Tanzania Gender Networking Program, Tanzania Women Leaders in Agriculture and Environment).

2.2 National policy milestones

Tanzania has undertaken since the mid-80’s a series of policies aiming to make its economy more productive. Tanzania’s Vision 2025 is the blueprint for sustained economic and social development. The National Strategy for Growth and Reduction of Poverty (NGRP or MKUKUTA) is a medium-term framework for implementing Vision 2025. It is based on an output-oriented strategy with emphasis on the development of economic productive sectors and the private sector, in particular the agriculture and SME sectors. NGRP is organized around the following three clusters:

Cluster 1: Growth and poverty-reduction

Cluster 2: Improved quality of life and social well-being

Cluster 3: Governance and accountability

The main policy steps regarding the promotion of S&T-based innovation are summarised below¹⁵:

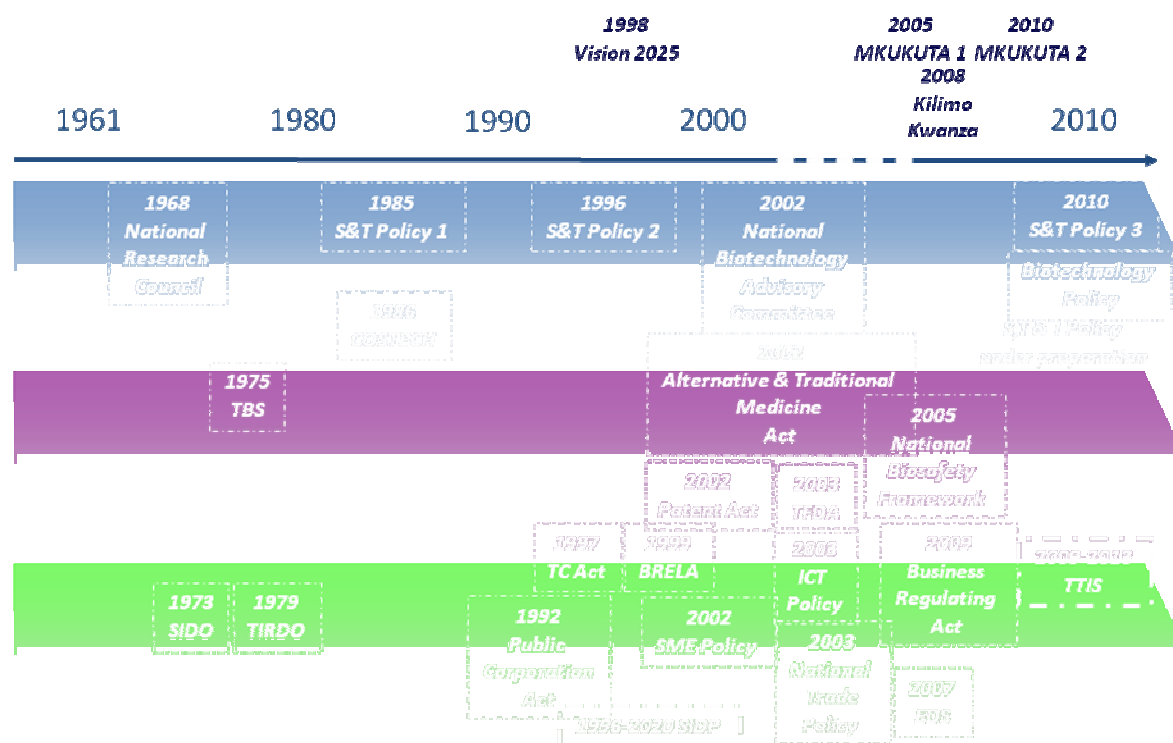


Figure 5. Summary of National Policies’ framework related to the promotion and commercialisation of Science & Technology-based products

¹⁴ Dr. Kingamkono, Director Research Coordination and promotion, COSTECH, personal communication February 2011

¹⁵ Kilimo Kwanza, Agriculture First Policy; MKUKUTA (Mkakati wa Kukuza Uchumi na Kuonda Umaskini in Kiswahili): National Strategy for Growth and Reduction of Poverty

2.3 The National Biotechnology Policy

The Ministry of Communications, Science and Technology has published two landmark policy papers in 2010 concerning both Research and Development and Biotechnology.

The mission of the National Biotechnology Policy is “to create infrastructure for research, development and commercialisation in biotechnology so as to ensure a steady flow of bio-products, bioprocesses and new biotechnologies for the social and economic development of Tanzania.¹⁶”

This key document formulates the following main priorities which need to be addressed in order to ensure that Tanzania “has the capacity and capability” to capture the benefits of biotechnologies:

- Coordination in the application of Biotechnology
- Institutional framework
- Legal framework on Biosafety
- Roles of Stakeholders
- Monitoring and evaluation
- Implementation: Strategic Plan & review of regulatory frameworks

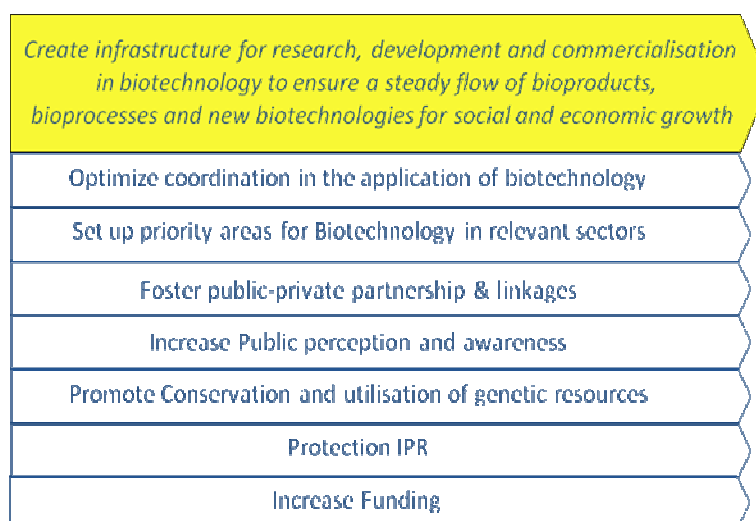


Figure 6. Summary of main National Biotechnology Policy priorities 2010

The Ministry of Communication, Science and Technology (MCST) coordinates S&T at national level given its role as Chief Advisor to the Cabinet on all related matters. The Ministry of Finance is responsible for the fiscal policy working through the Bank of Tanzania. Although sectoral ministries are individually responsible for their sectoral activities, their S&T activities carried out in affiliated research institutions are under the MCST umbrella:

- Ministry of Agriculture, Food Security and Co-operatives
- Ministry of Energy and Minerals
- Ministry of Water
- Ministry of Livestock and Fisheries Development

¹⁶ MCS&T, National Biotechnology Policy, 2010

- Ministry of Health and Social Welfare
- Ministry of Natural Resources and Tourism
- Ministry of Transport
- Ministry of Industry, Trade and Marketing

Business associations are recognized as stakeholders and include agriculture, commerce, industry and mining corporations.

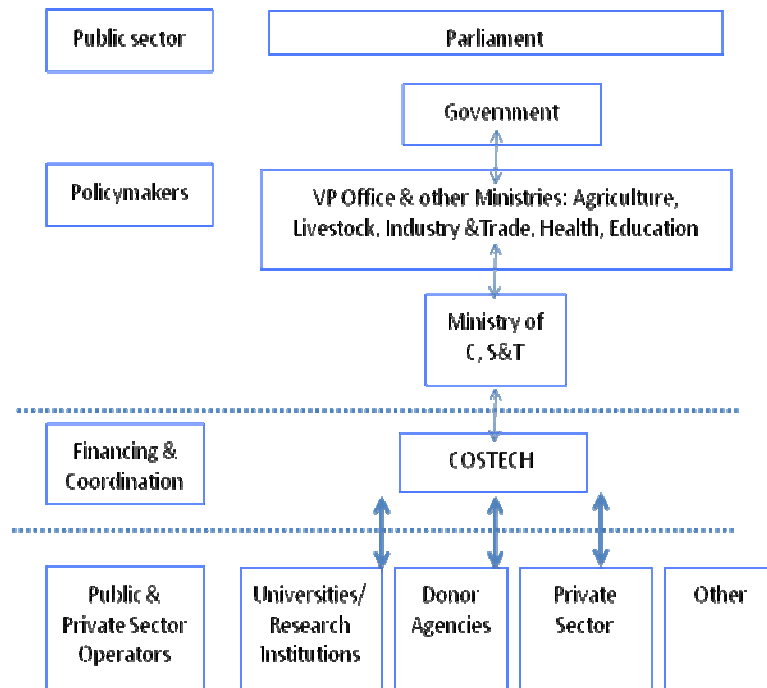


Figure 7. S&T stakeholders in Tanzania

The Commission for Science and Technology (COSTECH) is the implementation arm of the national science and technology policies in collaboration with nine R&D Advisory Committees and their associated national R&D institutions (ANNEX 3). COSTECH is a parastatal organisation established by an Act of Parliament in 1986 with the mandate to advise government on all matters relating to scientific research and technology development. COSTECH's mission is to foster knowledge-based economy through promotion, coordination of research, technology development and innovation for sustainable development in Tanzania. Its key roles are the following¹⁷:

- Advise the government on all matters relating to S&T
- Formulate policy on S&T
- Monitor and coordinate scientific research and technological development of all persons or body of persons
- Acquire, store and disseminate scientific and technological information
- Examine and promote Institutional R&D programmes
- Mobilize and supervise funds for R&D funds for R&D

¹⁷ COSTECH website <http://www.costech.or.tz>

- Foster regional and international cooperation
- Initiate, formulate and implement research policies/programmes

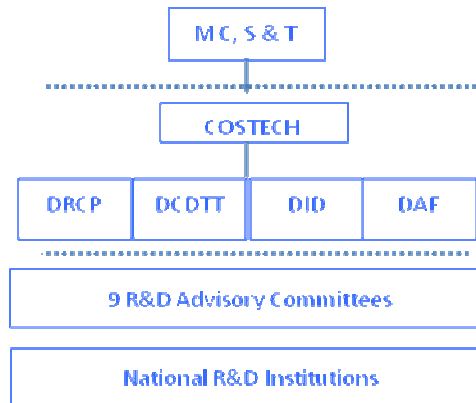


Figure 8. COSTECH and the implementation of S&T policy

At the interface of governmental S&T policy and research institutions, COSTECH has a key role in coordination and implementation.

2.4 Interplay of technology transfer systems in place

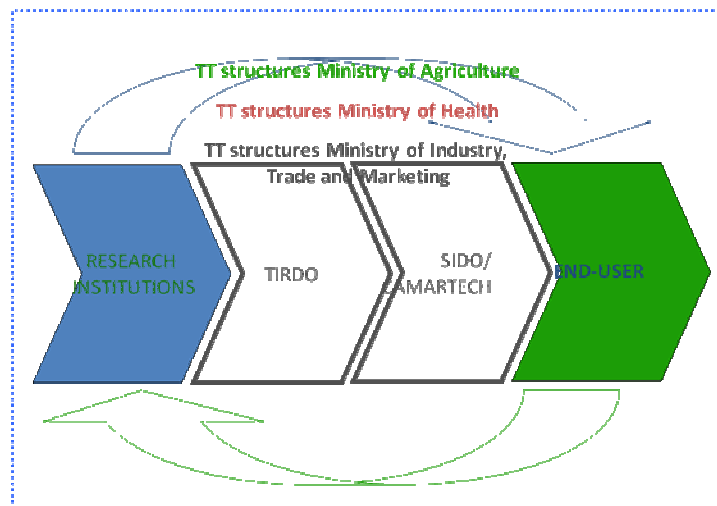


Figure 9. Tanzania interplay of existing technology transfer structures

The Ministries of Health, Agriculture and Industry benefit, via their affiliated research institutions, from technology transfer systems deployed throughout the country. Sector-related products such as improved seeds, bio pesticides, and agricultural machines are provided to end-users, although on a relatively small non-commercial scale. They also serve to collect information regarding demand. These channels can be used as preferential points of entry for the introduction, testing and piloting of more innovative products as well as for outreach, dissemination and awareness purposes.

3. Survey

3.1 Methods

Governmental, higher education and both public and private research institutions of interest were mapped based on prior knowledge, relevance and recent reports.

Interviewees from the selected institutions were sent a preliminary questionnaire (ANNEX 1) 2 to 4 weeks before the interview in order to collect background information for the interview and the report.

The information for the survey was collected through open-ended face-to-face interviews through purposive and snowball sampling. Interviews were carried out during 2 visits in November 2010 and February 2011. Over 40 people were interviewed from institutions across the biotechnology value chain. The public and private institutions visited are listed below (interviewees and their affiliation are listed in ANNEX 2):

3.2 Interviews

1. Government and Regulatory bodies

1	Ministry of Communication, Science and Technology
2	Council of Science and Technology
3	Ministry of Agriculture, Food Security and Co-operatives
4	Ministry of Industry, Trade and Marketing
5	Prime Minister's Office, Better Regulation Unit
6	Tanzania Food and Drugs Authority
7	Business Registrations and Licensing Agency
8	Medical Stores Department

2. Public Research Institutions

1	Sokoine University of Agriculture, Morogoro
2	National Institute for Medical Research, Dar es Salaam
3	Michocheni Agricultural Research Institute, Dar es Salaam
4	University of Dar es Salaam, Dar es Salaam
5	Central Veterinary Laboratory, Dar es Salaam
6	Nelson Mandela Institute of Science and Technology, Arusha
7	Tropical Pesticide Research Institute, Arusha
8	Selian Agricultural Research Centre, Arusha
9	Tanzania Industrial Research and Development Organization, Dar es Salaam
10	Institute of Traditional Medicine, Dar es Salaam
11	Tanzania Coffee Research Institute, Moshi

3. Private Research Institutions

1	Kilimanjaro Christian Medical Centre, Moshi
2	Ifakara Health Institute, Dar es Salaam

4. Private Sector

1	Shely's Pharmaceuticals, Dar es Salaam
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Table 5. List of Institutions Visited

3.3 Findings

Interviews across the research to commercialisation value chain provided insight into the missing links. In the following analysis these missing links, diagnosed in several recent reports and currently addressed by the Tanzanian related policy documents, have been connected to the relevant steps in the commercialisation value chain taking into account critical external factors including governance, funding and other framework conditions.

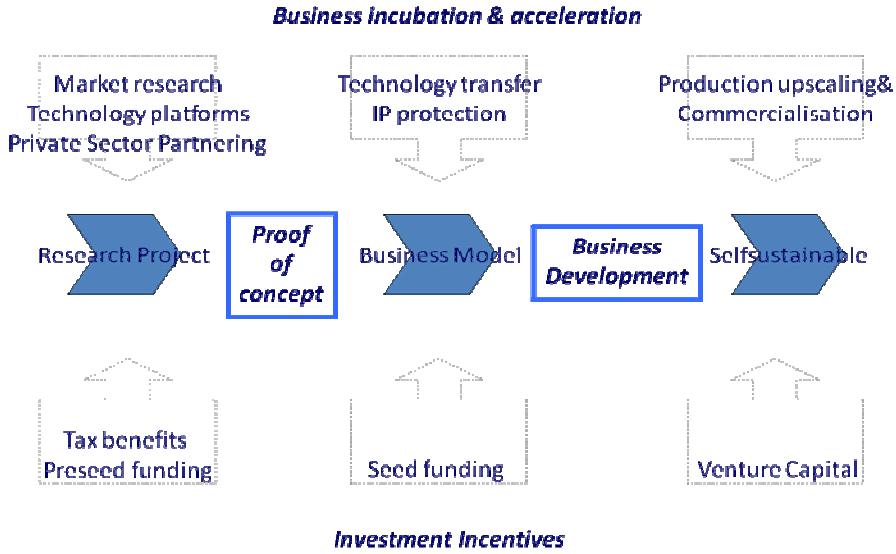


Figure 10. Biotechnology Framework

3.3.1 Governance, coordination and policy implementation

The interviews carried out at the Ministry of Communication, Science and Technology and COSTECH showed a close alignment of objectives. First steps towards the implementation of the Biotechnology and Research and Development Policies are being concretized with flagship projects such as the opening of the Nelson Mandela Institute of Science and Technology, the establishment of Academic Networks of Excellence, the creation of the Life Science Convergence Centre as well as centralized government-funded schemes.

At the Ministry of Trade, Industry and Marketing, despite recent improved conditions for launching businesses and exports^{18 19}, biotechnology-based companies do not appear to benefit from any specific status. The link between the National Biotechnology Policy and the SME Policy, currently under revision, has yet to occur. No fiscal incentives are yet envisioned for the biotechnology sector at this level. Although regulatory policies address biotechnology-related issues directly, business-promoting measures do not yet take into account this sector. Resource limitations were commented to

¹⁸ Programme for Business Environment Strengthening for Tanzania (BEST), Prime Minister's Office, 2009
¹⁹ Export Policy 2009

be the principal cause. The communication and coordination between the relevant ministries may need to be optimized in order to provide the resources for policy implementation.

For example regarding TRIPs-related patent exemptions²⁰ lack of coordination between the Ministries of Health and Social Welfare, Trade, Industry and Marketing and COSTECH appears to be hindering potential implementation and exploitation.

3.3.2 From research project to proof of concept

The critical step towards the conception of a product-related project(s) requires skilled personnel, adequate infrastructure and a certain long-term vision, which can be complemented by private sector partnerships in addition to financial, business and IPR support structures. Interviews at research institutions pointed to gaps at the following levels:

3.3.2.1 Funding

Research funding is currently principally donor-funded. The percentage of donor funds varies between 52 - 70 % according to sources consulted^{21 22}. These funds have greatly benefited research activities yet the following limitations have been pinpointed:

1. Calls are either collaborative or only for students, thus limiting the number of students and research lines as research topics are preselected.
2. Insufficient governmental funds for R&D. Despite the pledge in 2007 to increase R&D funding to 1% GDP, current funding is limited to 0, 18%. Most research is donor-funded by bilateral agreements therefore the country's main research interest may not be addressed. The following potential fields of application were suggested:

<i>Potential fields of Application</i>	
Diagnostics	<i>Antigen/antibody and Nucleotide-based</i>
Local disease	<i>Cholera, food-borne and zoonotic diseases</i>
Drugs & Vaccines	<i>Traditional Medicine</i>
Industrial microbiology	<i>Tools to understand biodiversity Microbial, plant</i>
Food microbiology	<i>Genetic characterization Microorganisms, plants</i>
Biodiversity	<i>Biobanks</i>

Table 6. Potential demand-driven fields of application of biotechnology

3. Donor-funded collaboration may not go beyond field-research without any added-value technology transfer
4. Lack of private sector collaboration leaves academic research disconnected from additional private funds as well as market needs

²⁰ Losse, K. et al, The viability of local pharmaceutical production in Tanzania, GTZ, Germany, 2007

²¹ Madikizela, M., Mapping Research Systems in Developing Countries, *Country Report: The Science and Technology System of Tanzania*, Centre for Research on Science and Technology, University of Stellenbosch, South Africa and Institute for Research and Development, France, published with the support of the UNESCO, 2007

²² Mukama, B.C. and C.S. Yongolo, *Development of S&T system and experience of Tanzania on S&T data collection*, COSTECH Presentation at the Regional Workshop on Science and Technology Statistics, Entebbe, Uganda, 17-22 September, 2005

3.3.2.2 Training

The first biotechnology and industrial microbiology academic degrees were set up respectively in 2004 at SUA and 2005 at UDSM. The majority of graduates are subsequently employed in research institutions. In addition to academic technical skills, complementary training was called for to nurture scientific relevance as well as bioentrepreneurship:

1. Research projects should be designed beyond lab techniques with support at government level and universities linking with the relevant departments at universities.
2. There is currently a lack of a critical mass of researchers with complementary skills in order to carry out world-scale research e.g. bioinformatics
3. There is a lack of convergence at project, personnel and infrastructure level. This lack of convergence in certain cases was due to a lack of coordination at higher levels. In several cases scientists sent abroad for critical training were hindered upon their arrival from putting their newly gained knowledge to practice due to infrastructure shortfalls.

3.3.2.3 Technical and technology transfer support structures

1. Technology Platforms

The need for relevant technology platforms was voiced across research institutions. For example at the Chemistry Department at UDSM, samples were sent to the United Kingdom for fine chemical analysis. The demand for infrastructure needs to be coordinated. In many cases expensive infrastructure supplied by vertical donor-funded projects was out of use due to lack of long-term planning. Local and regional technology hubs should also provide upgrading, supplies and maintenance services.

There is currently a proposal for a centre of excellence with a new funding model based on networking to supplant external funds. Bilateral agreements between research institutions shall include budgetary elements including training and material and improve research coordination and resource sharing.

2. Interface personnel and structures

Research institutions appeared to lack technology transfer input at the beginning of project conception. There was also a certain lack of awareness regarding IPR issues.

3. Fiscal incentives

Currently there are no fiscal incentives, nor earmarked funds, for product development at research institutions at public or private level.

3.3.3 Beyond Proof of Concept

Certain research centres despite a high number of running demand-driven research activities and products or services at proof of concept stage are not close to commercialisation due to insufficient up scaling capacity. A lack of coordination between demand for resources and training was mentioned in addition to the following gaps:

1. Interface technology transfer professionals:

- Sustainable business plan based on market research
- Link research to public and private funding as well as fiscal incentives

2. Limited production facilities/capacity

- GMP facilities for vaccines, traditional medicine or chemical derivatives
- Sufficient planting area to upscale tissue culture for commercialisation

3. Insufficient technical know-how

e.g. Fruits do not attain export quality requisites due to lack of:

- Uniformity: variety in size in high production scale
- Disease-free clean plant material e.g. cassava, banana introducing disease-free variety using combination tissue-culture & pesticide package
- High yield

4. Lack of formal national accreditation systems

Research centres providing consulting services, e.g. Environmental Sciences Department at UDSM, underscored the need for recognized accreditation. Samples that could be easily analyzed locally are sent abroad at a much greater expense.

5. IPR awareness and enforcement

A majority of researchers across disciplines were unaware of IPR protection issues. Those who were aware lamented the lack of enforcement mechanisms. The issue of ownership of IPR generated in academia did not appear clear at institutional nor national level.

3.3.4 Sustainable up scaling

Among the research centres visited only MUHAS and NIMR Traditional Medicine Departments and CVL had gone beyond poc stage and actively envisaged commercialisation. GMP up scaling facilities as well as funding to support increased production to address a bigger market were the critical issues. The MUHAS Traditional Medicine Department has a small GMP donor-funded unit for poc and small local production. Private sector partners have been sought and negotiations are ongoing. The NIMR Traditional Medicine Department also reported the construction of GMP-compliant up scaling facilities.

An important influence on potential markets is the attitude of the public towards biotechnology products. Acceptance of biotechnology varies between health, agricultural and industrial applications, but also within applications. Successful commercialisation of biotechnology-based products needs to take into account effective communications policies for products that may not benefit from high public acceptance.

3.3.5 Preliminary list of products in the pipeline

The following products were disclosed during interviews. This list is by no means exhaustive and represents most probably a fraction of ongoing projects. Interviewees mentioned more products but their additional lists could not be integrated due to time constraints. The list incomplete as it is, showcases nevertheless the R&D capacity of Tanzanian research institutions.

Product/Service	Institution	Stage of development
AGRICULTURE		
1. Tissue culture coffee plantlets	TACRI	Commercialisation
2. Tissue culture banana plantlets	MARI	Commercialisation
3. Tissue culture grape and cassava plantlets	MARI	poc
4. Biopesticides	TPRI	poc
5. Pest-control using small fish	TPRI	poc
6. Environmental testing	TPRI, UDSM	Commercialisation
7. GMO testing	TFDA	Commercialisation
8. Food safety testing	TIRDO	Commercialisation
HEALTH		
HUMAN		
9. Traditional Medicine: Benign prostate cancer	MUHAS	poc
10. Traditional Medicine: Asthma	MUHAS	poc
11. Traditional Medicine: Stomach Cancer	MUHAS	poc
12. Traditional Medicine- based Morizella juice	MUHAS	poc
14. Traditional Medicine: antimalarial	NMRI	poc
15. Odour-baited Mosquito traps	IHI	poc
ANIMAL		
16. Animal vaccines: thermo tolerant NewCastle Disease (I2), Brucellosis (S19), Anthrax, Black Quarter Disease	CVL	Commercialisation
17. Animal vaccines: Combination of anthrax and blackquarter (Tecoblax), Contagious Bovine PleuroPnuemonia (CBPP), Rift valley, Peste des Petits Ruminants (PPR)	CVL	poc
INDUSTRY/-related		
18. Cashew Shell Oil	UDSM	poc
19. Fire and water-resistant cashew chip brick	TIRDO	poc
20. Bio ethanol from wild cassava	TIRDO	poc

21. Environmental testing	UDSM	Commercialisation
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Table 7. Preliminary list of biotechnology-based products and services and stage of development

3.3.6 Potential for domestic substitution of imported bio products

Visits and interviews were carried out at the Tanzania Food and Drug Authority (TFDA), Medical Stores Department (MSD) and Business Registrations and Licensing Agency (BRELA) to report on imported bio products as well as those which are currently produced locally.

BRELA did not include sectoral classification or products in its registry. It was suggested to include these data. A preliminary targeted list of produced and imported bio products was requested at the TFDA but not provided within this report's timeline. The MSD did provide the price catalogue of essential medicines, diagnostics and hospital supplies, however this information alone is not sufficient to draw any conclusions for potential substitution of imported bio products by those produced locally.

The compilation of a list of bio products that are currently being imported but could potentially be produced domestically would be a useful indicator of marketability and commercialisation.

3.3.7 SWOT analysis of Tanzania's biotechnology value chain

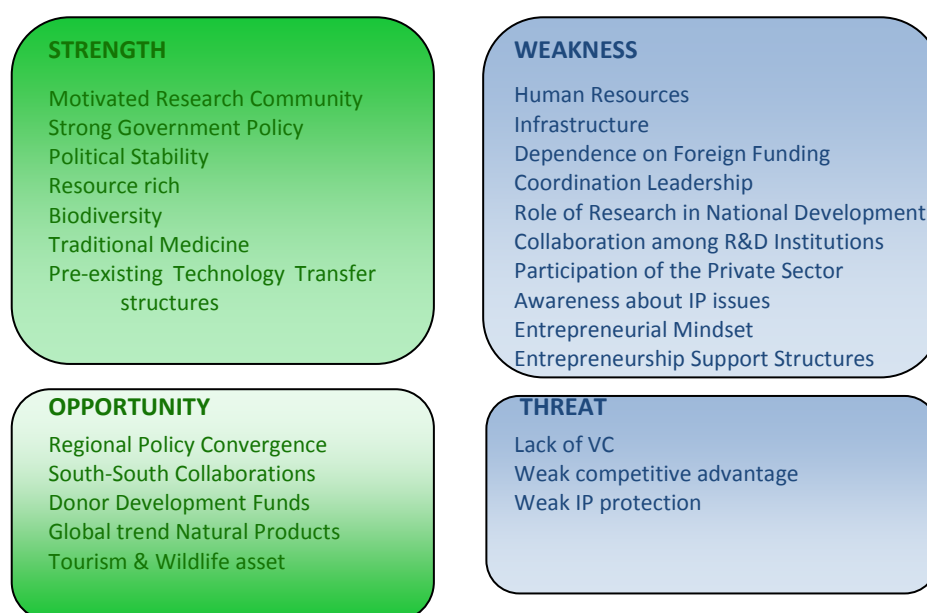


Figure 11. SWOT analysis of Tanzania's Biotechnology Value Chain

The SWOT analysis highlights the gap between policy and implementation and the potential for growth of the biotechnology innovation system in Tanzania.

4. Stakeholders Meeting

4.1 Rationale

During recent years, highly relevant and exhaustive reports have been written on Science and Technology in Tanzania by national and international experts. In addition, in 2010 the Tanzanian

Ministry of Communication, Science and Technology released two important national policy documents regarding Research and Development and Biotechnology respectively²³.

This survey since its inception aimed therefore, with the amiable approval of the UNESCO, to go beyond its strict “reporting” framework and by organizing an encounter between representative national stakeholders to identify jointly with the private sector the obstacles to the effective uptake and commercialisation of biotechnology-based products. This meeting was the first of its kind bringing together public and private players in biotechnology and bioentrepreneurship.

The meeting was articulated in two parts: a first morning session during which survey results were presented to a panel of international experts invited for the occasion. This session allowed open discussion between international S&T experts familiar with developing country settings. This meeting was enriched by the presence of the Director of COSTECH, one of the main national players in Tanzanian S&T as well as the national representatives of the UNESCO.

The second part held in the afternoon aimed to generate interaction among national public and private stakeholders based on the loopholes identified in the innovation value chain by the survey and the important points discussed in the morning. In continuation the meeting content, main outcomes and recommendations issued during the meetings are summarized. The invited experts’ bio sketches, the meeting agenda and presentations are in ANNEX 4.

4.2 Discussion Summary

4.2.1 PART I International Experts Meeting

Participants by alphabetical order: Salim Abdulla¹, Abdallah Daar², Imano Iriza³, Anthony Maduekwe³, Hasa Mlawa³, Gabriel Mergui⁴, Hasan Mshinda⁵, Kefas Mugittu¹, Antonel Olckers⁶, Golbahar Pahlavan⁷, Klaus Plate⁸, Wesley Ronoh², Peter Singer², Kenneth Simiyu²

Excused: Evelyn Mbede, Director of Research, Ministry of Communication, Science and Technology

Affiliations:

1. Ifakara Health Institute, Tanzania 2. McLaughlin-Rotman Centre Global Health, Canada, 3. United Nations Educational, Scientific and Cultural Organization (UNESCO), Tanzania, 4. Genopole International, France, 5. Commission for Science and Technology (COSTECH), Tanzania 6. DNAbiotec, South Africa, 7. Barcelona Centre for International Health Research, Spain, 8. Heidelberg Technology Park, Germany

The aim of this first workshop was to bring together international experts in Science, Technology and Innovation in order to discuss openly the findings of the UNESCO_IHI survey and highlight the most

²³ National Biotechnology Policy, Ministry of Communication, Science and Technology, The United Republic of Tanzania, 2010

The National Research and Development Policy, Ministry of Communication, Science and Technology, The United Republic of Tanzania, 2010

relevant points in order to optimize the content for the meeting with the national stakeholders that would take place subsequently.

The meeting began with participants' introduction and presentation. The IHI survey carried out between November 2010 and February 2011 was then presented and served as the main backdrop of the issues broached during this session where the gaps in the biotechnology innovation value chain in Tanzania and the most relevant next steps to strengthen it were discussed.

The main comments and recommendations address implementation and sustainability issues: coherent and sustainable implementation of the government policies regarding biotechnology was recognized as the biggest challenge.

The central role played by COSTECH was underscored. COSTECH's director, Hassan Mshinda, voiced the determination of the Commission to address the issues that would be raised by the panel.

There was a consensus regarding the importance of parallel implementation of the development of promising products while strengthening at the same time the biotechnology value chain and support infrastructure within the framework defined by the national R&D and Biotechnology policies.

The main recommendations of the expert panel regarding this parallel implementation are the following:

I. Leadership: the mission commando

COSTECH and associated agencies should have a clear mandate and the authority delegated by the government to implement the Science and Technology agenda. Gabriel Mergui mentioned the example of the creation of Genopole in France when a "commando" was given the mandate to create the centre with full authority to address all obstacles.

II. Entry point implementation

The development of a limited number of products after due diligence from the non-exhaustive list of products identified by the IHI survey as having reached proof of concept stage or beyond was recommended.

Peter Singer proposed that the most commercially viable products be selected among the preliminary list presented and to provide the conditions for their development. The service-based ones followed by diagnostics should be among the first candidates to consider. He said that this strategy has worked well in Rwanda where due diligence was done on three initial stage products with 100 000 \$ preseed funding. A reduced staff of three was hired at the local convergence centre to develop the products until commercialisation. He mentioned that direct foreign investments were just starting to focus on African companies and local job creation.

Klaus Plate agreed on the importance of success stories in strengthening the sector, focussing on the Tanzanian and African markets. Companies can be started with products based on their own home

market such as animal vaccines, traditional medicine-based: juice, antimalarial, biopesticides, services for the protection of the environment and the tourism industry.

Abdullah Dar underscored the importance of existing successful initiatives particularly in agriculture such as WEMA²⁴. He said that seed companies in developing countries tend to be commercially viable.

Regarding the biotechnology-based services that should be considered for commercial development, Gabriel Mergui stressed the importance of food and environmental testing. He mentioned a company that has developed a portable DNA diagnostics device (30-40,000 samples per run, HIV-1 and HIV-2, bird flu) that is going to market soon. Such devices could be used in African settings and would short-cut the system by building the capacity to use the highest technology.

Antonel Olckers said that bio-banks for both human and wildlife are a great opportunity but they did not appear on the list. There is a need and urgency to establish these in a systematic and regulated manner for the benefit of Tanzania.

III. Incentivise cooperation & synergies

All participants agreed that success stories are effectively a major entry point, however success needs many other entry points that should be dealt with in parallel, not one after the other. Communication between public and private sector is a key factor and should be promoted otherwise it will not just happen.

Klaus Plate said that to promote public-private partnerships in Germany in the 1990s, the Federal Government set up a competition to develop bioregions. Regions having established such partnerships received federal funding. Technology transfer requires a strong commitment of all parties: people to scout through the labs, to set up a translational system, funding schemes and incentives and other entry points that help at earlier stages to help make a successful company.

1. Mapping poles and clustering

Clustering know-how, capacity and equipment was recognized by all as the best way to optimize resources.

An exhaustive mapping of people, projects and product pipelines was recommended. This would give insight into potential strengths and real gaps that need to be addressed at cluster level.

Antonel Olckers mentioned the concept of an internet-based mapping tool for products and people i.e. skills and competencies. Using such a tool when looking for a specific skill, project or product in the biotech sector would be the click of a button away.

²⁴ WEMA <http://www.aatf-africa.org/wema/>

2. Partnering with the private sector

Antonel Olckers said that another key aspect is communication between the stakeholders from public and private sectors. She said that initially it was thought in academia that the private sector was not needed to develop technologies. Now there is a bottleneck to get the technology commercialised. Only recently researchers and decision-makers have begun to realise that the public and private sectors are connected: “we either swim or sink together”. In South Africa, the new IPR from Publicly Funded Research Act (2008) has helped to change this mindset. It is now clear to everyone that research, whenever possible, must end as a product in the market.

3. Co-incubation

Gabriel Mergui mentioned co-incubation between different countries. He mentioned that 6 years ago, this was discussed with eGoli BIO (in RSA) where Genopole scanned products, did market research, pre-audited IP and gave business planning and development advice. The main issue is capacity building. He suggested setting up a virtual incubator with Genopole, Heidelberg Science Park and their European partners similar to the Bio-Common Tools Project²⁵ he mentioned during his presentation. The co-incubation of a start-up company by two incubation systems allows an innovative company to take advantage of all the resources of both locations. The second location should bring the missing items in the original one, such as expertise in IP, mentoring on strategic positioning, access to best level technology platforms (GMP, combinatorial chemistry, genomics, nanotechnology, etc.), International network grants services, human resource to complete staffing and venture capital. Needless to say that co-incubating a company means the absolute necessity to discard any temptation of predation.

IV. Funding

Gabriel Mergui underscored the importance of seed funding. Giving the first dollar is an important step. He said that Genopole provides such funding. However the signature on the cheque is more important than the amount since it provides credibility to convince other potential financiers.

Hassan Mshinda said that a competitive and transparent government funding system was being put into place and that it could also be used for seed fund purposes for the commercialisation of proven technologies.

V. Training

Training was identified as one of the main gaps.

Antonel Olckers said that having an entrepreneurial mindset is key. In science school scientists are not exposed to entrepreneurship and need to be trained by including it in university science curricula. Contact with engineers could also be promoted to take up a problem-solving approach.

²⁵ <http://www.bioct.net/>

Existing programmes such as the UDSM Centre of Entrepreneurship and the SME program by the Gatsby Foundation were briefly discussed. It was mentioned that these programs had a rather local scope and the majority of scientists were not exposed to this training. However, provided the right incentives and linkages, such programs could be pivotal in entrepreneurship training.

Wesley Ronoh said that developing the right HR in pharmaceutical manufacturing and to develop mid-level HR for those resources would enable launching pilot production facilities within short timelines.

Klaus Plate said that hiring the best people at an early stage is a good strategy to reduce failure rates.

4.2.2. PART II International Experts and National Stakeholders Meeting

Additional participants to the abovementioned: Paul Gwakisa⁹, Kenneth Hosea¹⁰, Wilson Marandu¹¹, Maximillian Mpina¹, Julius Mugini¹², Julie Makani¹³, Chanasa A. Ngeleja¹⁴, Juma Shamte¹⁵, Debora Sumari¹, Brian Tarimo¹, Newton Temu¹²

Affiliations:

9. Sokoine University of Agriculture, 10. University of Dar es Salaam, Tanzania, 11. Alpha Seed Company, Tanzania, 12. Mikochei Agric Research institute, 13. Muhimbili University for Health and Allied Sciences, Tanzania, 14. Central Veterinary Laboratory, Tanzania, 15. Katani Sisal Ltd., Tanzania

Excused: Shely Pharmaceuticals

The main issues and recommendations address the lack of linkage between Academia and Industry.

I. Linking Academia and Industry

1. Training biotechnology and entrepreneurship skills

“We have to change the education system to train scientists.”

Lack of adequate training to promote entrepreneurship among scientists was discussed among stakeholders, especially those from academic institutions. Previous initiatives as well as existing ones such as the Business Centre at the UDSM and the Tanzania Gatsby Foundation SME project were mentioned. The main issues with these programs are their limited geographic scope as well as their sustainability.

Hasa Mlawa said that the structure of University has to change. Some universities now have deputy vice-chancellor of Research and Innovation. He said that we have to change the game, to work out strategies and plans to change the game at our institutions on a continuous basis and train as many Tanzanians as possible, not only in biotech but also in manufacturing. Universities are not just centres for doing research and writing papers; they should also transform promising ideas into value. UNESCO is prepared to take the lead to change this game. At university level in order to combine

science and innovation people need to be exposed to the relevant kind of skills and competencies. Education lacks entrepreneurship. He reported that a stakeholders meeting the government accepted in principle that a science education policy will have to be designed and that bio-entrepreneurship will be a central part of this. It has been planned that Tanzania will send a delegation to Tshwane University of Technology and bio-entrepreneurship training in graduate programmes has been commissioned.

Interlinked with the lack of training is the unavailability of support structures. Juma Shamte said that it is important to encourage students to take business courses. However even if they do take these courses, they may not become entrepreneurs in the future due to lack of support structures.

2. Incentives for academic researchers to develop products

Participants commented that currently there are no incentives at public research institutions for scientists to dedicate time to any activity other than research. The evaluation of researchers is solely based on academic and publication credentials. Patents or activities related to product development are not taken into account. Research development achievements are not connected to remuneration. Also all scientists may not have interest in entrepreneurship and there is therefore a need for interface professionals to take up projects where they are left off by scientists or to provide support for their development.

Kenneth Hosea said that many publications, papers and thesis can be developed into products. However, certain scientists may find working for 2 to 3 months to develop a product very boring to do. Interface/support agents are needed to go around digging how many products can be put into the market.

Julie Makani said that IPR and translating research into products are slowly happening, encouraged and leveraged but are not recognised currently. Where is the gap, what are the issues, where to invest to get results? Funding information would benefit from more transparency.

3. Partnering with the Private sector

a. Lack of a common vision

The challenge of going from the research stage to commercialisation was discussed. The lack of response capacity at the academic research level was mentioned. The following practical case experienced by two of the participants present, Kenneth Hosea from UDSM and Juma Shamte from Katani Sisal Ltd., served as an example of the support structures required to streamline the collaboration between academic researchers with the private sector.

Juma Shamte said that the private sector SME's job is to make it (R&D) work for the masses. Profit is up for negotiation. All experience the challenge of going from the research stage to commercialisation. SMEs need to push sometimes for collaboration; sometimes that opportunity is

denied. There is a need for strategic planning. When UDSM was approached, it was difficult to convince the University to allow their knowledge to be used, they preferred to sell rather than to partner. There was not a clear policy for the University to engage in such a venture. Despite the good output of research institutes in Tanzania, due to lack of support structures it is a challenge for SMEs to access this knowledge and to take it to commercial product.

b. Lack of support structures

Juma Shamte said that a lot of research is being done, but most end up on the shelf due to the lack of support structures to allow us (private sector SMEs) to interact and commercialise. R & D must lead to the market. There should be a focus on research for local products to start selling where you are. In Tanzania, the existing structures have been developed in 1960's, the economy has changed a lot since and is more capitalist now. The existing structures may not be sufficient to support the new economy. Public or private sector, who should be doing that? Who should take the lead?

The lack of support structures was confirmed at academic level as well as a certain wariness regarding partnering with the private sector.

Kenneth Hosea said that previously (early 2005 - 6) UDSM Departments had received visits directly on a one-to-one basis without a clear vision of the benefits of product development nor partnering with SMEs. There was a need for an agency, better equipped to negotiate with business people than academic researchers, that could act as an intermediate and to follow them up. The University has now an appointed patent officer to assist in dealing with the private sector. Researchers are now advised that when any negotiations are ongoing to avoid speaking with business people and to contact the patent officer. He also reiterated the lack of incentives for collaborating in such projects as currently having patents on one's CV does not give any benefit in the academic ladder: commercialising research findings at the moment is not really attractive.

Juma Shamte said that the issue for the private sector SMEs is the output. Compensation for output is very much organic. Certain Universities focus on R&D to be commercialised, the right mechanism may be negotiated. SMEs are also comfortable in outsourcing. Academic partners need to know whether they want to be a partner. Public partners need to identify how they want to come in and can dictate what piece of the pie they want. We need to know the way we want it as a nation.

Gabriel Mergui said that all projects, depending on their development stage, need varying levels of support. If you leave a researcher in front of development problems, he is not formatted for that. Full-time project managers are our solution at Genopole, not remote experts.

Juma Shamte said that SMEs need support structures to support the commercialisation of R&D, to facilitate collaboration with the numerous national and international entities. This type of support is not provided by any government agent.

c. Lack of recognition of the private sector as an equal partner

Referring to the S&T stakeholders diagram presented (Figure 7), Juma Shamte said that private institutions should be on par with research institutions. He said that both work in collaboration with COSTECH.

II. Funding

Participants from both public and private sectors lamented the lack of seed funding for R&D-based projects.

Julie Makani said that unlike Northern countries, there is no national funding scheme to promote research. Nor does the private sector support research, as there is no link between industry and academia. Although product and services' commercialisation is slowly happening, the issue of funding remains. If you bring a UK grant for 2,2 million pounds to Tanzania, the government does not match it. This lack of funding does not motivate academic research.

Gabriel Mergui said that in the US during the late 90's only 5% of the funding of innovation work (the so-called "Death Valley") was brought by VC. The bulk was brought by public funding. Therefore if the very mature innovation system of the US relied so much on public funding and so little on VCs, what could be expected from less mature systems such as the European Union or developing countries? Strong and clear involvement of public policies and funding is in the essence.

Juma Shamte said that it was imperative to have access to more R&D funding than what the government is currently contributing. He said that the activities carried out at his company have a national impact and would benefit from widespread acceptance.

III. REGULATORY and IPR

Biosafety regulation was mentioned as preventing the use of GMOs in the country. GMO vaccines should be encouraged, may be a way of making most effective vaccines, but policies are currently limiting their use.

Gabriel Mergui said that IP has to be protected. It is however not necessary to own IP, but you need know-how. Some seeds are public. One threat that has not mentioned so far is Tanzania's great mining potential: mining means pollution. Soil remediation has lot of biotech behind it. Using biotechnology-based tools need not necessarily be IP-based.

IV. Linking research to the market

Juma Shamte said that the first question that comes to mind seeing the list of products presented is : "who demands these products?" There needs to be a strategic plan. In addition to a tax regime, it is important to provide an environment that is more protective of local industries and more supportive. Tan environment that favours us (local SMEs) from the very beginning, supports our growth, so that

more can be collected in the end. He suggested that VAT should be removed on locally produced raw material, in order to allow local industry to produce more, then the finished products can be taxed.

Chanasa Ngeleja said that the problems encountered in diagnostics and vaccinations are the reliance upon biologicals produced elsewhere. This is inefficient to detect our local pathogens. Producing biologicals for us should be using our own local strains.

1. Strengthening the domestic market against foreign competition

Private sector participants said they lack favourable conditions, such as tax regimes that support ideas developed domestically, loans, incubation structures to compete against foreign products whereas foreign companies may benefit from up to 5-year tax holidays. An example was given of the closure of a local fermentation plant following importation of fermented ethanol from South Africa entailing 1000 lost jobs.

In addition, it was mentioned that Industry has little trust in technology from within the country, but happy to receive technology from elsewhere. Anyone can import something that can easily be made in Tanzania. Business suffers from unfair competition; imports should not happen if we have the products in the country, there is a law enforcement limitation in this regard.

Wilson Marandu said that inertia was another problem related to the “made in Tanzania” brand. This inertia is built into the mind of the consumer. Therefore imports can represent a threat to the successful commercialisation of domestic products. For example tomato seeds imported from overseas are not adapted to this climate. Now even foreign companies are packaging these local seeds because they are the best.

Klaus Plate said that the idea to develop biotechnology by protecting development for some time in Tanzania may work in some niche area, but in biotechnology there is no chance to set up national strategy to protect it long term.

2. Production capacity

Juma Shamte said that the private sector experiences both evils: they undertake production, have to provide themselves the facilitating technologies and build the local capacity. He said that they had tried to interact with the national interface production structures (TIRDO, SIDO, TEMDO) but that their capacity was too low and they could not keep up with pace of development in the commercial sector. Machines were sometimes outdated, the raw materials procured insufficient. They (Katani Sisal Ltd.) finally had to build their own internal capacity imported from China.

The lack of quality management (QM) systems in the production process was mentioned. Putting in place such systems would allow the accreditation of certain biologicals and other high quality products that could then be commercialised. The establishment of QM systems in production should be encouraged.

4.3 Recommendations

The following recommendations pool all the comments and suggestions from the survey and both stakeholder meetings. The expert panel advised a parallel multipronged approach, these recommendations should therefore be considered simultaneously and not sequentially.

I. Reinforce Leadership

- a. Entry-point implementation based on list of biotechnology-based products which are close to commercialisation
- b. Provide a national strategic plan for Biotechnology Research & Development priorities
- c. Provide the executive arm (COSTECH) with a clear mandate for implementation at all levels including:
 1. Regulatory and IPR
 2. Funding mechanisms (soft loans, matching funds)
 3. Tax incentives
 4. Biotechnology-based Start-ups
- d. Promote domestic biotechnology-based products and services
 - i. Provide preferential taxation conditions for selected domestic biotechnology-based products
 - ii. Provide national quality management and accreditation systems for domestic biotechnology-based products and services
 - iii. Improve marketing of domestic products at national and regional levels
 1. Participation in sectoral fairs
 2. Dissemination of S&T breakthroughs
- e. Reinforce gender streamlining in S, T & I
 - i. Set up mentoring mechanisms
 - ii. Implement Gender Policy at Institutional and Governmental levels

II. Promote Cooperation and Synergies

- a. Between Ministries
 - i. Provide an inter-ministerial Strategic Plan for Science, Technology and Innovation stating clearly the mandate of all the players
 - ii. Coordinate relevant facilitating policies and regulations for the commercialisation of biotechnology-based products
 - iii. Allocate necessary personnel and funding resources
- b. Between research institutions
 - i. Map people, equipment, projects and product pipelines in an updatable online database to promote effective clustering and resource-sharing
 - ii. Provide technology platforms based on research and cluster priorities
- c. Between public and private stakeholders

- i. Provide matching funds for collaborative projects bringing together partners from academia and industry
- ii. Incentivize private sector participation and/or the creation of biotech-based start-ups
- iii. Show-case academic biotechnology-based R&D know-how and added-value in project catalogues or sectoral forums

III. Promote value-creation in academic biotechnology-based research and development

1 Nationally

- a. Revise the evaluation of academic researchers' credentials at Higher Education Institutions to reward patent registration and product development and commercialisation
- b. Incentivize patent registration by defining beneficial inventor IP ownership rights
- c. Provide Technology Transfer support structures and personnel
 - i. Market research
 - ii. Business plan
 - iii. IPR
 - iv. Funding
 - v. Lobbying
 - vi. Strengthen the ongoing Life Science Convergence Centre initiative

2 Regionally and Internationally

- d. Establish regional and international co incubation partnerships for business acceleration
 - i. Access to regional centralized technology platforms
 - ii. Access to VC
 - iii. Access to mentoring and training capacities by incubating systems
 - iv. Access to new technologies aimed at analytical or production purposes
 - v. Benchmarking of success and failure stories

IV. Increase Government Funding

- a. Research projects addressing local needs
- b. Preseed funding schemes for Proof of Concept
- c. Seed funding for business development

V. Provide Training

- a. Mainstream gender parity at all levels
 - i. Promote women role models and mentors
- b. Provide complementary entrepreneurship training to scientists

- i. Academic courses
 - ii. Periodic sectoral meetings at local, regional and international levels with Industrial stakeholders
 - iii. Send professionals to international conferences and workshops of international associations of science and technology parks or incubators.
- c. Promote interdisciplinarity in S, T& I
 - i. Promote training of interface professionals in collaboration with Business and Engineering schools
 - ii. Bioentrepreneurship contests

VI. Improve communication with public at large about biotechnologies

- a. Increase awareness about S & T and its benefits
- b. Increase acceptance of biotechnology-derived products
- c. Increase acceptance of domestic products and services

5. Conclusions

Tanzania has a vibrant research community and a nascent biotechnology-based sector. Addressing the gaps in policy coordination, incentives and support structures identified by national stakeholders in combination with hands-on product development have been recommended as preliminary steps towards the commercialisation of biotechnology-based products and services. The translation of recommendations of reports into concrete actions requires skills and resources to set out a roadmap, monitor progress and deliver. The next step for Tanzania is the implementation of its policies by the empowerment of its scientific and business community and increased public awareness.

6. References

- Africa Competitiveness Report, World Economic Forum, World Bank, African Development Bank, 2011
- Basic Education Statistics in Tanzania (BEST), Ministry of Education and Vocational Training, Revised National Data 2006-2010
- Blanke J. and Sala i Martin, World Economic Forum, *Examining Africa's Competitiveness*, World Bank Competitiveness Report 2010
- COSTECH website <http://www.costech.or.tz>
- Economic Outlook, *Tanzania*, African Development Bank/ OECD 2008
- Gaillard, J., *Country Report TANZANIA*, Stockholm IFS& Paris, December 2001
- Juma, C. and Serageldin I., *Freedom to innovate: Biotechnology in Africa's Development*. Addis Ababa: African Union and New Partnership for Africa's Development, 2007
- Hidalgo, C., *Discovering Southern And East Africa's Industrial Opportunities*, Economic Policy Paper Series, German Marshall Fund of The United States, 2011
- Kingamkono, R.R., *Gender, Science and Technology in Tanzania: A situation Analysis*, Scientific and Technology Conference, Golden Tulip, 24-26 May 2006
- Limonta, M., *Report on a visit to selected Tanzanian biotech research institutes and/or entrepreneurs to assess their activities and the state of art of biotechnology*, 2010
- Losse, K. et al, *The viability of local pharmaceutical production in Tanzania*, Report commissioned by the German Federal Ministry for Economic Cooperation and Development (GTZ), 2007
- Madikizela, M., Mapping Research Systems in Developing Countries, *Country Report: The Science and Technology System of Tanzania*, Centre for Research on Science and Technology, University of Stellenbosch, South Africa and Institute for Research and Development, France, published with the support of the UNESCO, 2007
- Tanzania Ministry of Communication, Science and & Technology, *National Biotechnology Policy*, 2010
- Mukama, B.C. and C.S. Yongolo, *Development of S&T system and experience of Tanzania on S&T data collection*, COSTECH Presentation at the Regional Workshop on Science and Technology Statistics, Entebbe, Uganda 17-22 September, 2005
- National Center for Biotechnology Information (NCBI), PubMed database, February 2011
- Programme for Business Environment Strengthening for Tanzania (BEST)*, Prime Minister's Office, 2009
- Shah, R. et al., *Science-based health innovation in Tanzania: bednets and a base for invention*, BMC International Health & Human Rights , 10(Suppl1): S4, 2010
- Simuyu, K. et al, *Stagnant Health Technologies in Africa*, Science, 330:1483-84, 10 December 2010
- The Bioeconomy to 2030, Designing a policy Agenda*, OCDE, 2009
- The Value of Biotechnology*, The Biotechnology Industry Organization, May 2010

South African Regional Universities Association (SARUA), *The state of public Science in SADC*,
produced by Centre for Research on Science and Technology, University of Stellenbosch,
South Africa, 2008

Wolter, D., *Tanzania the Challenge of moving from Subsistence to Profit*, Business for Development,
OECD 2008

World Bank, *Country Profile Tanzania*, 2010

UNDP, *Human Development index Tanzania*, 2010

7. Annexes

ANNEX 1

Preliminary list of visits

Government/Regulatory	Academic	Red	Green	White
Ministry of Communications, Science and Technology	UDSM	Shely's Pharma LTD	MARI	Kitani Sisal Ltd
COSTECH	SUA	CVL	TPRI	
Ministry of Agriculture and Food Security	NIMR	IHI	SARI	
Tanzania Food and Drug Authority	MUHAS		TIRDO	
Ministry of Industry, Trade and Marketing	KCMC		TACRI	

	Preliminary Questionnaire
1	Date foundation
2	Funding: private/public
3	Fields of Research/Expertise
4	5 main ongoing projects
5	Number of students/employees per field
6	Number of graduates, PhDs/field
7	% of women
8	10 recent Publications/patents
9	Collaborations with other National Centres
10	Collaborations with International Centres

ANNEX 2

List of interviewees

1. Government and Regulatory bodies

1	Ministry of Communication, Science and Technology	- E.I. Mbede - R.T. Chibunda	Director of Research Deputy
2	COSTECH	- H. Mshinda - R. R. Kingamkono - N. Nyange - G.S. Shemdoe	Director Director Research Coordination and Promotion DTT IPR
3	Ministry of Agriculture, Food Security and Co-operatives	- E.M. Achayo	Director of Policy and Planning
4	Ministry of Industry, Trade and Marketing	- P.B. Marwa - J.A. Lyatuu	Assistant Director Principal Trade Officer SME Division

		- F. Roman - C.V. Lyimo	Industrial Economist Industrial Engineer
5	Prime Minister's Office Better Regulation Unit, BEST Regulation Centre	- B. Lyimo	Advisor Regulatory Reforms

1	TFDA	- H.B. Sillo - R. Wigenge - A.M. Khea	Director General Director Biotechnology GMO Director Medical Devices
2	BRELA	2 persons	Business Registry
3	Medical Stores Department	1 person	Purchase Department

2. Public Research Institutions

1	SUA	- P.S. Gwakisa	Prof. Immunology and Biotechnology Genome Science Centre
2	NIMRI	- H.M. Malebo	Director & deputy of Research
3	MARI	- E. Kullaya - E.Mneney	Principal Agricultural Research Officer & WEMA country Coordinator Senior Research Officer
4	University of Dar es Salaam	- G. Mtui - Q. Mgani	Chemistry Dept, UDAS,
5	CVL	- R. Sallu	
6	NMU	- B. Muamila	Director
7	TPRI	- E.E. Kimaro - E.F.A. Njau	Director General Director of Technical Service
8	SARI	- C. Lyamchai - S. Kweka - I. Mamuya - J. Senbosi	Senior Research Officer Head Bean Program Research Officer Head of Dissemination
9	TIRDO	- L.C. Manege - M. Ndosu	Director of Industrial Research Head of Division Food & Biotechnology
10	MUHAS	- Z.H. Mbwambo - J.J. Magadula	Director Institute of Traditional Medicine Senior Research Fellow

3. Private Research Institutions

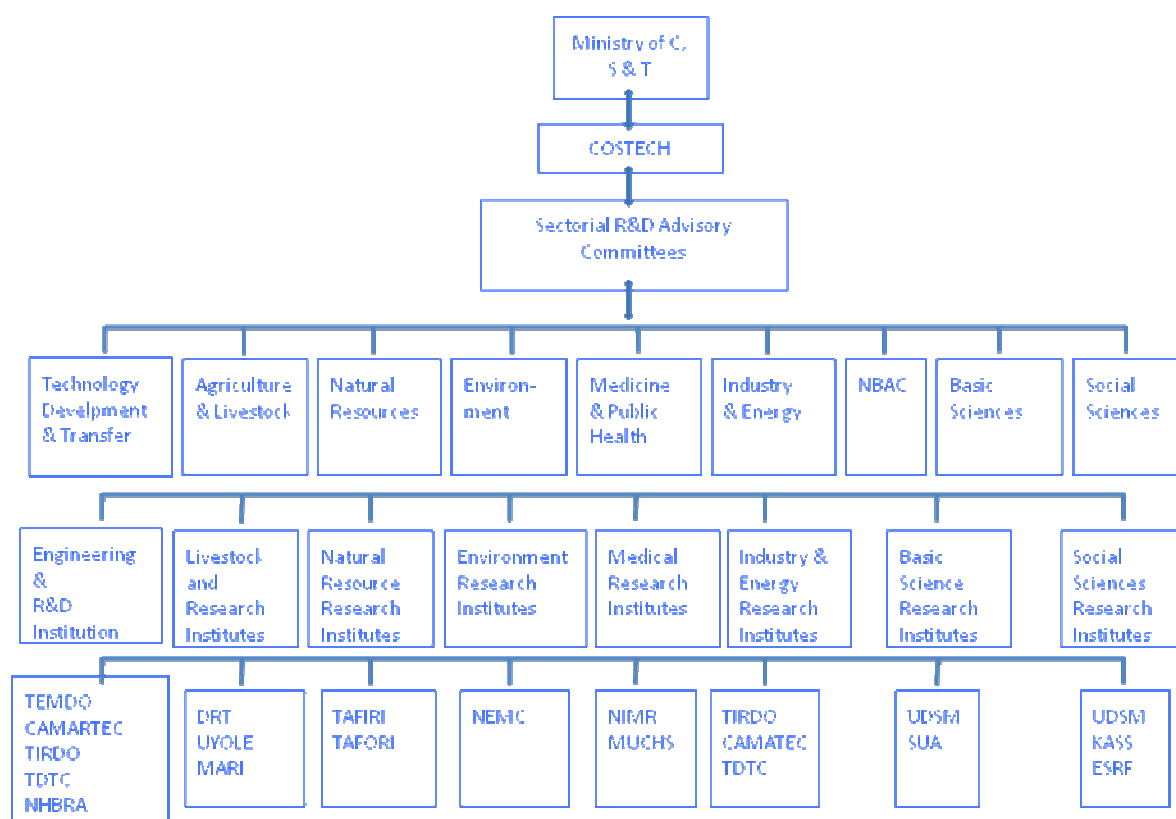
1	TACRI	- D.L Kilambo	Head Crop Improvement Department
2	KCMC	- G. Kibiki - F. Moshia - R. Kavishe	Director Biotechnology Centre Biotechnology Centre
3	IHI	- S. Abdulla - G. Killeen	Director Senior Researcher

4. Private Sector

1	Shely's Pharmaceuticals	- H. Upreti	Chief Marketing Officer
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ANNEX 3

COSTECH and affiliated R&D committees



ANNEX 4

Bio sketches panel of international experts by alphabetical order:

Abdallah Daar is Professor of Public Health Sciences and of Surgery at the University of Toronto, and Senior Scientist and Director of Ethics and Commercialization at the McLaughlin-Rotman Centre for Global Health, University Health Network and University of Toronto. He is also Chief Science and Ethics Officer of Grand Challenges Canada

After medical school in Uganda and London, England, he went to the University of Oxford for postgraduate clinical training in surgery and in internal medicine, a PhD in transplant immunology, and a fellowship in transplantation. His academic career has spanned biomedical sciences, organ transplantation, surgery, global health, and bioethics. He works in various advisory or consulting capacities with the UN, the World Health Organization and UNESCO, and was a member of the African Union High Level Panel on Modern Biotechnology.

He is a Fellow of the Royal Society of Canada, the Academy of Sciences for the Developing World (TWAS), the Canadian Academy of Health Sciences, and the New York Academy of Sciences, and is a Senior Fellow of Massey College, University of Toronto. He is a member of UNESCO's International Bioethics Committee and of the Ethics Committee of the Human Genome Organization.

Professor Daar is Chair of the Board of the Global Alliance for Chronic Diseases and Chair of the Advisory Board of the United Nations University International Institute of Global Health.

Gabriel Mergui is Managing Director of the International Department of Genopole. A graduate of the HEC business school and the Paris-I/Sorbonne University, post graduate in Econometrics, Gabriel Mergui began his career at the French National Institute for Agronomic Research (INRA), as an Economist specialized in technology transfers in the food processing sector. He then, served as a Diplomat at the French Embassy in Mexico City (Agricultural Attaché). Back in France he co-founded the Technology Transfer Office of INRA. At the request of INRA he co-founded the Company JTS, that sells vegetable seeds for tropical zones.

In the private sector, he has worked successively in several venture capital and biotechnology-based companies.

In 1998, he co founded the Incubator of the Genopole Science Park at Evry in the south of Paris and served as a member of the Board of Managing Directors of Genopole 1er Jour, the Seed Fund he has designed and helped to structure. Since 2009 he coordinates the EU-FP7 Consortium “Bio Common Tools” (Bio-CT) aiming at sharing different kinds of tools between EU Bio-Regions, for the benefit of innovative SMEs.

Antonel Olckers founded DNAbiotec[®] in 2001. Her expertise in science, innovation, and business is combined in DNAbiotec[®] which is a knowledge based core biotech company. Over the past ten years the company generated IP and translated its IP into products. Dr Olckers is a strong advocate for empowering the next generation of scientists in Africa. To this end DNAbiotec[®] provides training via the Essential Series of Short Courses[™] which contains the lessons learned by DNAbiotec[®] in translating ideas to products. Via these courses she shares the DNAbiotec[®] experience of the steep learning curve that a scientist faces in business. She currently serves on the National Biotechnology Advisory Committee (NBAC) of South Africa, and previously on the board of eGoliBIO life sciences incubator. She is currently appointed as an extra-ordinary professor at the University of Pretoria where she lectures annually in “Biotech Business Management” and “IP management” at the Bioentrepreneurship course.

Klaus Plate was CEO of the Heidelberg Technology Park, Germany, until 2010. He studied law at the Universities of Hamburg, Freiburg and Göttingen, Germany where he finished his PhD in 1971 and qualification as lawyer and judge in 1972. He was Director of the Department of General Administration (COO) and Economic Development of the City of Heidelberg until 2007 and CEO of the Technologiepark Heidelberg GmbH (Heidelberg Technology Park), the first BioPark in Germany, from 1994 until March 2010. During this time the Park developed from 6.000- to 50.000-sqm lab and office space, from 17 to more than 80 companies and from 300 to 1.400 jobs. From April to December 2010 Klaus Plate was Senior Advisor of the Heidelberg Technology Park. Klaus Plate has been President of the International Association of Science and Technology Parks (IASP) from 2000 to 2002. He was Member of the Advisory Committee of Zhongguancun Science Park, Beijing, China, from 2000 to 2002 and he served as Member of the Board of the Council of Biotechnology Center, Biotechnology Industry Organisation (BIO), Washington DC, USA. Klaus Plate is currently member of the Steering Group of the Council of European BioRegions (CEBR), Cambridge, UK/ Brussels, Belgium and Advisory Board Member of the World Incubator Network, The Hague, The Netherlands.

Wesley Ronoh is Postdoctoral fellow at the McLaughlin-Rotman Centre for Global Health within the Commercialization pillar. Wesley holds degrees in Pharmacy (B.Pharm) and Business Administration (MBA) from the University of Nairobi, as well as Medicinal Chemistry (Msc) from the Jomo Kenyatta University of Agriculture and Technology. He has served as the Intellectual Property, Technology Transfer and Marketing Manager at the Kenya Medical Research Institute (KEMRI) since 2001. Wesley is a member of the Expert Committee on Drug Registration (CDR) of the Pharmacy and Poisons' Board, Kenya and member of the Technical Expert Committee on TRIPS and Access to Medicines (TECTAM). He sits on the Board of Management of the Kenya Industrial Property Institute (the national IP office) and is a member of various national policy development committees in Kenya, including the standing committee on South–South cooperation within the Ministry of Planning and Vision 2030. He has previously served as a regulatory affairs consultant to 3M Pharmaceuticals, East Africa subsidiary and has undertaken voluntary Good Manufacturing Practice (GMP) audits on three local pharmaceutical manufacturers as part of a KEMRI technical evaluation team.

Ken Simiyu is studying for his PhD at the Institute of Medical Sciences, University of Toronto. Kenneth received a Bachelors degree in Veterinary Medicine and Masters degrees in Veterinary Public Health and Business Administration from the University of Nairobi, Kenya and completed a Masters in Public Health degree at George Washington University, Washington DC. In Nairobi, Kenneth provided marketing research and business development expertise to the Kenyan government, the Kenyan Trypanosomiasis Research Institute and international pharmaceutical companies based in Nairobi. In Washington, Kenneth worked with the International Organization for Migration (IOM) as a health policy consultant. His supervisor is Dr. Peter Singer.

Peter Singer is Chief Executive Officer of Grand Challenges Canada and Director at the McLaughlin-Rotman Centre for Global Health, University Health Network and University of Toronto. He is also

Professor of Medicine and Sun Life Financial Chair in Bioethics at University of Toronto, and the Foreign Secretary of the Canadian Academy of Health Sciences. He studied internal medicine at University of Toronto, medical ethics at University of Chicago, public health at Yale University, and management at Harvard Business School.

Singer chairs the Canadian Academy of Health Sciences' new assessment on Canada's Strategic Role in Global Health. He has advised the Bill & Melinda Gates Foundation, the UN Secretary General's office, the Government of Canada, Pepsico, BioVeda China Venture Capital Fund, and several African Governments on global health.

In 2007, Dr. Singer received the Michael Smith Prize as Canada's Health Researcher of the Year in Population Health and Health Services. He is a Fellow of the Royal Society of Canada, the Canadian Academy of Health Sciences, the US Institute of Medicine of the National Academies, and The Academy of Sciences for the Developing World (TWAS).