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Co-Designing Science in Africa

First steps in assessing the sustainability science approach on the ground

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Co-Designing Science in Africa

First steps in assessing the sustainability science approach on the ground

Foreword

By Heide Hackmann and Xing Qu

The shift towards a sustainable society is one of the central challenges of our times. To meet this challenge, the global community committed to the 17 Sustainable Development Goals (SDGs) as a pathway to a sustainable future that leaves no one behind.

Science, technology and innovation (STI) will play a critical role in this global endeavour. However, to reach the full potential of STI for SDGs, the science-policy-society interface will need to be reinforced and the scientific community, policy-makers and the general public will need to come together in the search for joint global responses.

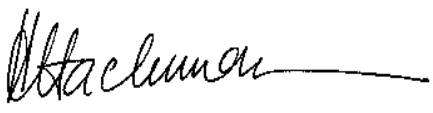
Based on co-design and co-production of knowledge oriented towards problem-solving, the key objective of sustainability science is to develop new knowledge, technology, innovation and holistic understanding, which will allow societies to better address global and local sustainability challenges. This will require greater international scientific collaboration that can harness scientific perspectives and expertise and strengthen institutional science advisory mechanisms at both the global and national levels to support evidence-based decision-making in support of a sustainable global transformation.

Building collective creativity and capacities in science and innovation for sustainable development is an even greater challenge than simply building capacities in science and innovation. It implies training practitioners to conduct research that is systematically inter- and transdisciplinary, to understand complex systems, to deal with irreducible uncertainty and to engage with a wide range of societal stakeholders and knowledge systems to address sustainability challenges.

Throughout the present book, there is a clear recognition of the critical role of sustainability science towards achievement of SDGs, and the importance of STI policy instruments in mobilizing national capacities and ensuring spaces for collaboration among stakeholders. The authors also recognize the value of intra-regional, South-South and global cooperation in harnessing the full potential of sustainability science to generate evidence-based solutions to common global challenges preventing sustainable development.

The five case studies in sub-Saharan Africa – four of the five being regional research hubs for sustainability science – illustrate key opportunities and constraints to the application of sustainability science principles in the continent.

Based on these findings, the authors formulate important recommendations for science and policy. These are in line with the 2017 *UNESCO Guidelines on Sustainability Science in Research and Education* and, more broadly with the 2017 *UNESCO Recommendation on Science and Scientific Researchers*. Several recommendations focus on capacity building in sustainability science along the lines of ongoing activities of the International Science Council (ISC) in this field. The specific focus on the African region and gender in science, combined with the balanced mix between policy and practice, makes this publication unique. We are confident that the work presented here by a broad array of experts will help to advocate for profound changes in the regional approach to STI and, through a multiplier effect, enhance the contribution of science and innovation to a more sustainable and equitable development of Africa.



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Preface

By C. Aguirre-Bastos, J. Chaves-Chaparro and S. Aricò

Editorial team

It is now widely recognized that human activities, driven almost exclusively by the pursuit of economic growth, are affecting the stability of the Earth's systems, thereby creating multiple sustainability challenges. Currently, several planetary boundaries have been crossed, risking a shift to a much less hospitable state, endangering economic growth, damaging efforts to reduce poverty and exclusion, and leading to a deterioration of human well-being in many parts of the world.

This situation calls for new approaches in science and technology, in order to achieve the necessary improvements in both policy and practice, reconfiguring the flow of knowledge between people, organizations and institutions, the interaction between them, and establishing a set of incentives for knowledge generation and its application. Traditional ways of policy-making in science can only deliver, at best, incremental progress that will not be enough to avoid crossing the threshold where damaging consequences cannot be slowed or reversed.

In this context, the concept (and practice) of sustainability science is considered as one such new approach. Sustainability science can be defined as a new emerging discipline, which adopts a solution-oriented, holistic approach to problems and perspectives, involving the sustainability of global, social and human systems. As such, it is disciplinary, interdisciplinary or transdisciplinary, and can be geared towards the generation of basic knowledge, applied technology or socio-cultural innovation, or towards exploring new governance or social and economic models. Sustainability science is thus an expression of both academic freedom and of academic responsibility towards societal issues.

Sustainability science is widely recognized and accepted as a bridge between various disciplines to address global challenges and, more recently, as a knowledge base for achieving the Sustainable Development Goals (SDGs). Sustainability science is also characterized by its ability to link social and ecological systems. This is clearly important, as facing common challenges can lead to strong community-based and participatory processes, calling for the co-design and co-production of knowledge that stems from research collaborations among scientists, non-academic stakeholders, business, indigenous and local communities, government and civil society.

The integration of different knowledge systems, including indigenous and local (traditional) knowledge, is one of the key challenges facing many developing countries.

Strengthening of the science-policy-society interface and co-production of knowledge, as well as future scenarios with innovative policy options, should be explored to lead effective actions for operationalizing and implementing SDGs and other international agreements at local, national and regional levels. In this regard, in addition to scientific considerations, sustainability science can also be seen as a political and societal option to build more inclusive, knowledge-empowered societies, by which natural processes are preserved to ensure the well-being of civilization.

Closely related to the continuous development of sustainability science, the Future Earth Initiative, launched in 2015 and sponsored by a consortium of intergovernmental and international organizations, aims to advance 'Global Sustainability Science', build capacity in this rapidly expanding area of research, and provide an international research agenda to guide natural and social scientists working around the world. Future Earth constitutes a global research platform designed to provide the knowledge needed to support transformations towards sustainability. The Initiative seeks to build and connect knowledge to increase the impact of research, explore new development paths, and find new ways to accelerate transitions to sustainable development.

In accordance with its mandate, UNESCO, with the support of the Swedish International Development Cooperation Agency (Sida), initiated a pilot project to develop and mobilize the capacities of five developing countries to participate in the Future Earth Initiative. The findings of this project are presented in this publication. We sincerely hope that these will help to promote global dialogues on how to define coherent and inclusive research and innovation systems within the sustainability science paradigm, with a focus on the developing world and on partnerships between developing and developed countries.

UNESCO recognizes that sustainable development should respond in an integrated manner to the complex challenges of today, and capitalizes on its interdisciplinary expertise and intersectoral mandate to support the implementation of the 2030 Agenda for Sustainable Development, with a special focus on developing countries and the Africa region. UNESCO's operational strategy for Priority Africa is aligned with the 2030 Agenda, which in turn fully integrates the 2063 Agenda of the African Union, as well as with the Common African Position (CAP), which foresees the mainstreaming of the sustainability science approach.

Ultimately, we hope that this publication will provide useful evidence supporting the need for multistakeholder discussions on how best to foster integrated, collaborative and action-oriented research to address interdependent and complex sustainability challenges in the five countries studied in Africa – Ethiopia, Kenya, Rwanda, Tanzania and Uganda – and beyond.

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Ms. Juliana Chaves-Chaparro is the UNESCO officer in charge of this publication in her role of coordinator of the UNESCO-Sida project for building and mobilizing developing countries capacities to participate in the Future Earth Initiative. She holds a M.Sc. in Environmental Sciences and a Diploma of Advanced Studies in Sustainable Land Use Planning, together with a Masters in STI Policy Formulation and Evaluation. With an extensive carreer of more than 19 years, Ms. Chaves-Chaparro has proven expertise in the promotion of the science-policy-society interface, specially through the formulation of policies to promote research capacities and sustainable development. She has more than 15 years of international experience in the formulation, management and evaluations of projects in Europe (CONCERTO+, LIFE, FP7 and Horizon 2020 programs), Latin American and the Caribbean (including one year in the University of Panama) and Asia Pacific regions (UNESCO-Japan project in support of the IPBES). Her longer professional experience is, however, in sub-Saharan Africa where she has been working in more than 20 countries within the UNESCO-AECID capacity-building programme for science, technology and innovation (STI) policies through the UNESCO Global Observatory of STI policy instruments (GO→SPIN). From 2011-2013, she was based in Ethiopia working as environmental and climate change advisor in climate change to the UN-Environment liaison office and the Horn of Africa Regional Environment Center and Network in the University of Addis Ababa.

Ms. Chaves-Chaparro, as UNESCO focal person, has participated in the formulation of two Horizon 2020 successful project proposals namely: Responsible Research and innovation Networked Gloally (RRING) and Grounding RRI Practices in Research Performing Organizations (GRRIP). She is currently supporting their implementation and finalizing her PhD thesis on the contribution of science to SDG´s in Africa.

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Executive summary

By Carlos Aguirre-Bastos, Juliana Chaves-Chaparro and Salvatore Aricò

In accordance with its mandate, UNESCO, with the support of the Swedish International Development Cooperation Agency (Sida), conducted a pilot project to develop and mobilize the capacities of five developing countries in Africa (Ethiopia, Kenya, Rwanda, Tanzania and Uganda) to participate in the Future Earth Initiative. The Initiative was designed to promote global dialogue on: 1) defining coherent and inclusive research and innovation systems within the sustainability science paradigm, and 2) working in partnership with developed countries. The main findings of this project show:

1. The integration of various stakeholders and their cooperation with each other is of paramount importance in realizing the objectives of sustainability science

- To tackle and resolve sustainability challenges faced by Africa, it is deemed necessary to broaden the understanding of innovation, not only as an engine for economic growth, but also as a driver for societal well-being and environmental sustainability.
- Adequate frameworks formulating stakeholder engagement in mapping out specific issues, outlining problems and discerning conflicts in sustainable resource use and preservation can assist in the identification of stakeholders and development needs assessment.
- A proper review of knowledge transfer and community engagement, social impacts linked to innovation, and society's role in demanding the adaptation and articulation of the proposed solutions requires: 1) defining suitable processes and parameters to measure sustainability; and 2) obtaining and accessing sufficient data, especially with regard to impacts on the physical environment.
- Innovation strategies for sustainable development in the countries studied systematically neglect bottom-up initiatives. Yet, when active citizens and strong local democratic institutions 'own' and embody sustainable development, the likelihood of successfully shifting the trajectory of development towards the desired sustainability goals is higher, as action at the local level generates socially embedded changes in behaviour.

2. The relevance and value added of dialogues between diverse knowledge systems, and the need for transdisciplinarity

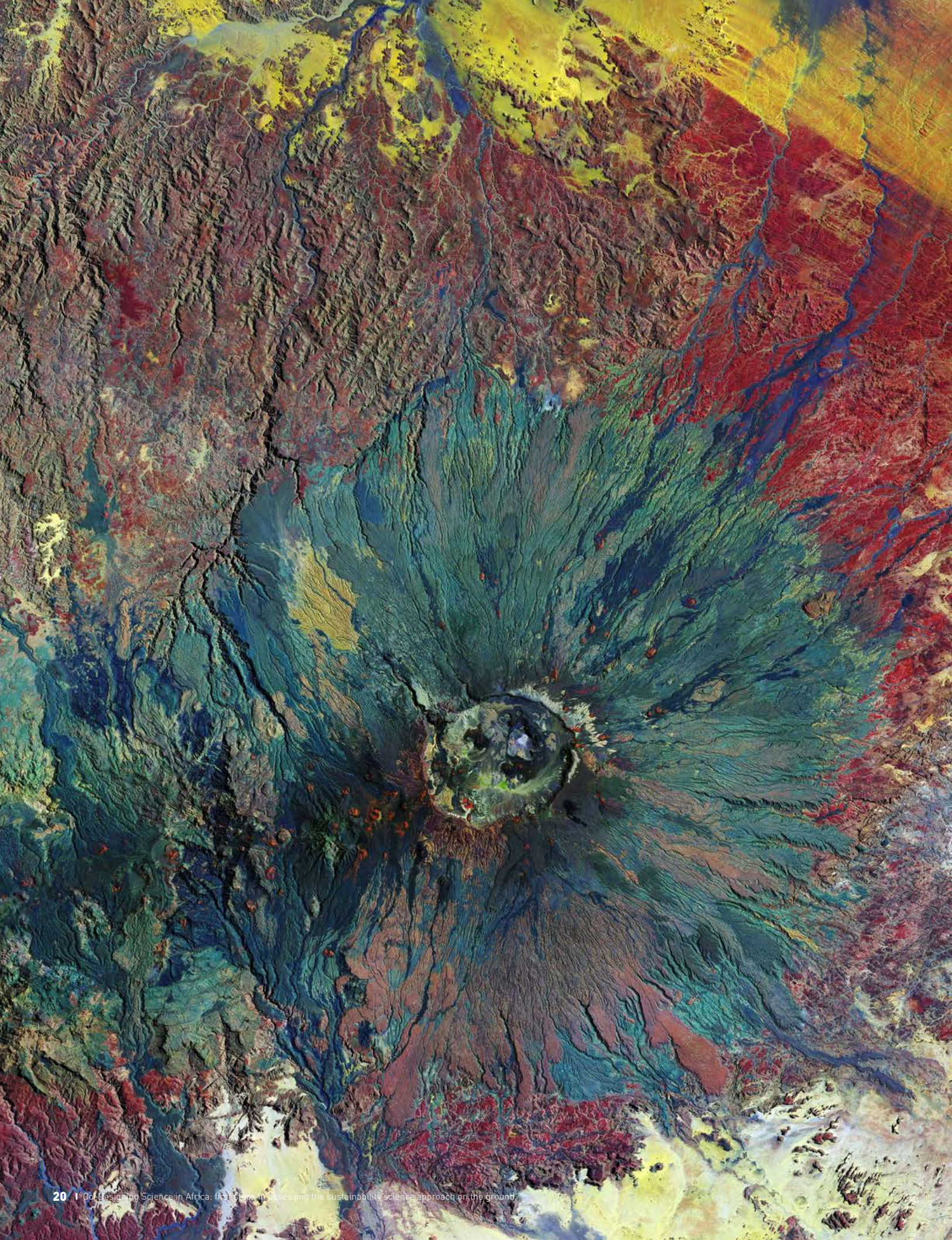
- Opportunities to pursue sustainability solutions are maximized when pathways for mobilizing existing diverse knowledge systems to generate contextually relevant knowledge are provided to address local sustainability challenges. Further progress towards understanding and tackling 'wicked problems' in the local and global context can be achieved by recognizing complementarities across these knowledge systems, while providing new insights for further testing sustainability science in action.
- Cooperation between indigenous knowledge systems and formal science is being fostered through ad hoc projects as well as policy instruments in several of the countries studied. Such cooperation faces inherent power dynamics and epistemological differences and challenges. In this regard, mapping and codifying indigenous knowledge may open up potential opportunities for collaboration with academics and industry practitioners.
- There is a need to mainstream indigenous knowledge by formulating R&D strategies. In fact, the impact of current home-grown initiatives on sustainable development could

be greatly enhanced within a more ambitious research and innovation agenda. In addition, this requires new policy instruments promoting more inclusive and interdisciplinary STI settings. There is also the need to mainstream transdisciplinary research into the national education and research systems.

3. The adequacy of STI systems and their role in supporting the sustainability science approach

- In the countries studied, policies still follow a linear model of innovation that focuses on STI actors working in a relational manner of knowledge transfer, without recognizing the complex interactions that exist between these actors within the national STI system. In addition to suffering from a lack of proper coordination geared towards improved and sustainable outcomes, STI policy implementation is beset by weak intersectoral linkages, limited opportunities for business-level technology absorption and limited sharing of STI learning across the sectors.
- Most of the objectives and goals of the ongoing national policies and plans for STI are geared towards meeting the economic elements of innovation and development, and are lacking not only an in-depth view of sustainability and inclusion challenges, but also specific and effective implementation measures, and funding.
- Against a clear and laudable increase in the body of theoretical, empirical data and knowledge on sustainability-related issues in Africa, there is an urgent need for the African research agenda to be driven towards more transdisciplinary, collaborative and participatory science. There is also a need to integrate the viewpoints and needs of relevant stakeholders in the scientific and non-scientific communities, so as to ensure that research outputs will be more relevant and useful to practitioners and communities, and suitable to the development needs and priorities of the continent.
- The participation of women in science, research and the innovation agenda-setting process should be mainstreamed into all sectoral programmes and incorporated into the design of specific gender equality policy instruments. Gender issues are overlooked in national STI policies, and very few policy interventions have been explicitly planned to change this situation. Specifically, no operational policy instruments to promote gender equality within either scientific and technological research activities, or specific incentives to encourage girls and women into STEM, are in place.
- Despite the observed weaknesses in the socio-economic innovation relationship, there are examples of commendable progress in African countries towards harnessing sustainable solutions, such as malaria/mosquito and livestock disease control, and sanitary technology. These innovations are primarily drawn from knowledge that has been shaped through iterative interactions between the communities and their environment, which have facilitated sustainability and been integrated into mainstream science and technology platforms.
- Promotional efforts are underway to increase private sector participation in innovation processes, through the establishment of a conducive and attractive environment for public-private partnerships or joint ventures. In addition, the nature of knowledge production is changing and becoming more evenly distributed as, in addition to research institutions, the knowledge and experience from industry and civil society also have a major role to play.
- Resource gaps, both human and financial, are recognized as key challenges constraining the ability of national innovation systems to address sustainability problems in a comprehensive way. Public finance for STI initiatives is unstable; researchers' participation in policy advice, either directly or through their scientific findings, is insufficient; and the short-term profit orientation of the private sector also hampers their involvement in STI. Other factors include limited infrastructure and equipment in research and higher education institutions; poor assessment of STI impact indicators and data availability; and a lack of implementation instruments in existing science and technology frameworks.
- Common transformation factors and recommendations for putting into practice sustainability science in Africa involve formulating and implementing education, research and innovation policies, through capacity-building and intraregional cooperation, in order to harness the potential of science to co-design and co-produce the knowledge and solutions required to address regional – and global – sustainable development agendas.

The pilot project undertaken in the five African countries has shown that they are setting the stage to improve the performance of their national innovation systems, but need new policies to focus on the economy-environment nexus and inclusion within the sustainable science paradigm.



1

Sustainability science: Where and how?

1. Sustainability science: Where and how?

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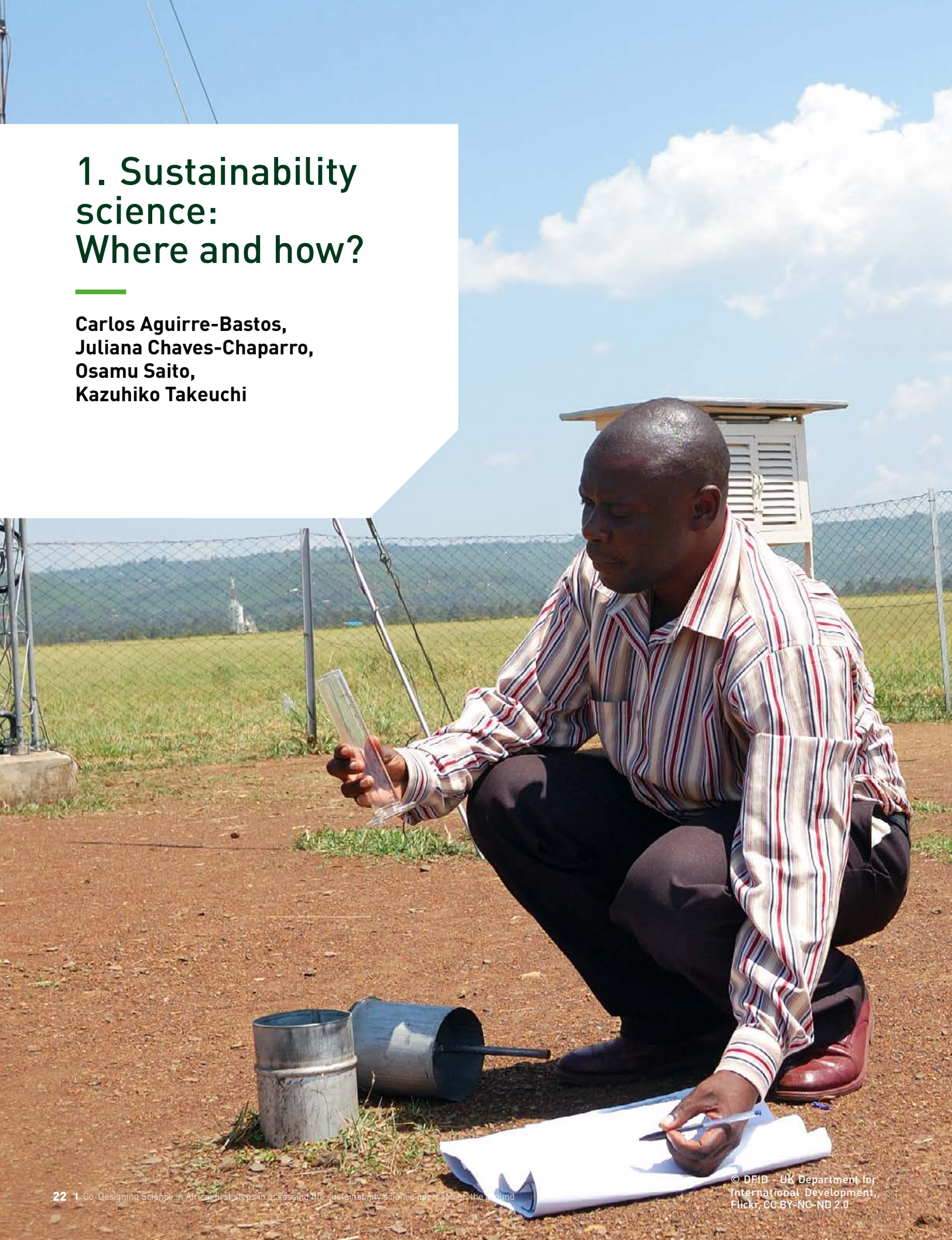

1.1. Sustainability science and its approaches

> *'During the 21st century, human society faces the daunting yet inspiring task of forging a new relationship with the natural world'. This new relationship is captured by the concept 'sustainability', that implies meeting current human needs while preserving the environment and natural resources needed by future generations. It is well recognized that 'Scientific knowledge has led to remarkable advances that have been of great benefit to humankind, together however, with environmental degradation social imbalance, and sophisticated weapons.'*
>
> (IAP, 2000).

Human activities, driven almost exclusively by the pursuit of economic growth, are affecting the stability of the Earth's systems. These activities represent a complex nonlinear network of multiple cause-and-effect relationships generating a large number of sustainability challenges, of key importance among which are: climate change; change in biosphere integrity; ozone depletion; ocean acidification; biogeochemical flows; land-system change (e.g. deforestation); freshwater use; atmospheric aerosol loading; and introduction of novel entities (e.g. organic pollutants, radioactive materials, nanomaterials and microplastics).

Currently, several of the above planetary boundaries have been crossed, risking a shift to a much less hospitable state, thereby endangering economic growth and damaging efforts to reduce poverty and exclusion, and leading to a deterioration of human well-being in many parts of the world (Steffen et al., 2015; Paus, 2013).

This situation calls for new approaches in science and technology in order to achieve radical improvements both in policy and practice, reconfiguring the flow of knowledge between people, organizations and institutions, the interaction between them and establishing a set of incentives (Schott and Steinmuller, 2017; Crespi and Dutrenit, 2013; Bokova, 2012). Traditional ways can only deliver, at best, incremental progress that will not be sufficient to avoid crossing a threshold, where damaging consequences may not be slowed or reversed.

The Future Earth (FE) initiative aims to face sustainability challenges by building and connecting knowledge in order to increase the impact of research, explore new development paths, and find new ways to accelerate transitions to sustainable development. The UNESCO-Sida Future Earth Capacity Project aims to bring developing countries into the FE initiative and global dialogues on how to define coherent and inclusive research and innovation systems within the sustainability science paradigm.

Sustainability science can be disciplinary, interdisciplinary or transdisciplinary; it can be geared towards the generation of basic knowledge, applied technology or socio-cultural innovation, or exploring new governance or social and economic models. Sustainability science is an expression of both academic freedom and of academic responsibility towards societal issues.

Komiyama and Takeuchi (2006) define sustainability science as a new emerging discipline which adopts 'a comprehensive, holistic approach to identification of problems and perspectives involving the sustainability of these global, social, and human systems.' They also emphasize 'structuring knowledge for sustainability science' and a 'transdisciplinary approach' as key drivers to promote this new discipline.

Sustainability science is widely recognized and accepted as a bridge between various disciplines to address global challenges and, more recently, as a foundation of knowledge for achieving the Sustainable Development Goals (SDGs) (United Nations, 2015). Over the last decade, the discipline has emerged as a science for transition and innovation towards a sustainable society and is widely accepted not only by research communities from various disciplines but also stakeholders from business sectors (Takeuchi et al., 2017). As per the findings of an Elsevier report on sustainability science in a global landscape, field research shows a tremendous growth rate of about 7.6% in all Scopus publications from 2009–2013, which is twice the average. Sustainability science research outputs attract 30% more citations than the average research paper (Elsevier and Sci Dev Net, 2015).

The transformation required to face sustainability challenges needs not only the development and diffusion of a wide range of new knowledge and technologies, alongside broader changes in the socio-economic landscape (Dutrenit and Sutz, 2014), it also requires a better participation of traditional and ancestral knowledge that has enhanced indigenous and local communities' abilities to cope with present and future global changes (Toledo 2003; Ruiz-Mallen and Corbera, 2013). These requirements require new ways of knowledge production and decision-making.

Sustainability science is characterized by its solution-oriented approach, ability to link social and ecological systems, and inter-

and transdisciplinary perspective (Kates et al., 2001; Komiyama and Takeuchi, 2006). The approach proposed by sustainability science can provide appropriate answers to real world problems as it is transdisciplinary, community-based and participatory. Its main principle accompanies the proposed co-design and co-production of knowledge (Pohl et al., 2010), that stems from research collaborations among scientists from different disciplines and non-academic stakeholders from business, government and civil society.

The implications of this solution-oriented approach are:

- Research on complex sustainability problems requires constructive input from various communities of knowledge to ensure that the essential knowledge from all relevant disciplines and actors related to the problem is co-designed and properly incorporated;
- Research on alternative solutions requires knowledge production beyond problem analysis – for example: goals, norms, visions and valuations systems are needed to provide guidance for transition and intervention strategies; and
- Collaborative efforts between researchers and non-academic stakeholders promise to increase legitimacy, ownership and accountability for the problem, as well as options for solutions (Lang et al., 2012).

1.2. Key challenges for the sustainability science approach

The challenge for the sustainability science approach is that scientists and indigenous and local knowledge holders might be sceptical of the reliability, validity and other epistemological and methodological aspects of collaborative research. Also, practitioners and other stakeholders might be sceptical regarding the practical relevance of the results. The differences between traditional science and sustainability science also disrupt the capacities required to conduct research.

In order for this kind of collaborative effort to be successful, it is important to focus on environmental and social challenges – the so-called 'wicked problems', due to their complexity and interrelational nature – enabling mutual learning processes and fertilization across researchers from different disciplines, as well as indigenous and local knowledge holders; and aiming to create knowledge that is solution-oriented, socially robust and transferable to both scientific and societal practice (Surr et al., 2002), with special regard to policy-making (Carden, 2009).

The enhancement of the science-policy-society interface lies in making effective connections between key stakeholders, including governments, scientific communities, think tanks, the private sector and civil society actors. This dialogue and cross-fertilization are required to support the evolution of the sustainability concept, as well as to ensure good science, technology and innovation STI governance to enable an integrated, inclusive approach to knowledge production and its effective contribution to address societal needs.

From this viewpoint, sustainability science is not just about scientific inquiry. The sustainability science paradigm incorporates a concrete normative and ethical context which is instrumental to the achievement of the Paris Agreement and the UN agenda 2030 for Sustainable Development. Therefore, political and philosophical issues – including the central question: 'Sustainability of what?' – play a key role in the assessment of 'sustainability science' and in understanding the sustainability scientist's role (Clark and Dickson 2003; Willmott, 2014). In this regard, in addition to scientific considerations, sustainability science is essentially a political option to build more inclusive, knowledge-empowered societies, by which natural processes are preserved so as to ensure the well-being of civilization.

Given the new principles described above, it is necessary to reassess different issues, and different questions that come to mind: What are the competences required? What are appropriate quality standards and criteria for this type of research? What type of interventions are appropriate and by whom? Who sets the research agendas? What are the characteristics and the role of the researcher in the new paradigm? These are questions that urgently need to be answered (Göransson et al., 2016; Wittmayer and Schäpke, 2014).

In the context of different global discussions taking place today, there are additional issues that need to be discussed in relation to the contribution of sustainability science to global environmental challenges:

- Women and girls make up more than half the world's population and they are often more deeply and differently impacted than men and boys by poverty, climate change, food insecurity and lack of healthcare. When an enabling gender equality environment is set, countries, organizations and institutions increase their innovative capacity and competitiveness. The scientific endeavour benefits from the creativity and vibrancy of the interaction of different

perspectives and expertise. Gender equality encourages new solutions and expands the scope of research (Göransson et al., 2008; Huyer, 2015). Therefore, women's involvement in scientific and policy spheres is essential to properly define the world's sustainability agenda and find innovative solutions.

- Developing countries have particular challenges, *inter alia* high poverty and inequality and contextual conditions, including biocultural diversity, that require analysis and methodologies adapted to their reality. These factors can greatly influence the set of valuations/motivations required to generate knowledge and its effective translation into sustainable solutions. Therefore, it is necessary to acknowledge the development nuances and take advantage of the interactive and evolutionary characteristics of sustainability science to enable fresh insights into the notion of sustainability and to define alternative and customized development models (Aricò, 2014). This will accelerate the necessary transition from the concept of 'catching up', usually attributed to developing countries, to integrated and inclusive knowledge producers and designers of their own customized sustainable development paths.

Photo 1.1. Women are the majority of the poor and assume bigger burdens towards household resilience
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- In developing countries, a large percentage of knowledge is generated around universities. These institutions are thus of importance, not only for the more obvious issue of capacity-building, but also for the mobilization of multiple stakeholders in the exchange, production and dissemination of knowledge. A discussion of their role is thus of great importance. (Brundenius and Göransson, 2010).
- The majority of publications in sustainability science are by high-income countries (254,629: 76% of all publications in sustainability science in the period 2009–2013). Low-income countries only produced 2% of the publications in this field, and most of them are the product of the cooperation with developed countries. This indicates that there is still a need to strengthen the research infrastructure and scientific cooperation networks of and among developing countries, in particular low-income countries (Elsevier and Sci Dev Net, 2015), as well as to address context-specific sustainability challenges and provide comparative tools to develop tailor-made policy advice.
- In particular, and although not yet fully connected, the African region appears active in the global research network in sustainability science, mainly with the USA, Canada and West Europe. South Africa and East African countries (Kenya, Ethiopia, Tanzania and Uganda) that are the regional research hubs. This is of course related to the nature of sustainability science, which requires global collaboration. However, the low publication rate and minimal internal African/East African cooperation or South-South cooperation is a major issue in the design of relevant knowledge to guide alternative development paths adapted to specific regional contextual factors.
- Interactions between distant places are increasingly widespread and influential, often leading to unexpected outcomes for sustainability (Liu et al., 2013). 'Telecouplings', as they are known, refer to various distant interactions which are increasingly important to understand present socio-ecological systems. Including telecouplings, interactions between nature and humankind have become, and will continue to become, more complex and uncertain, especially under climate change conditions. At the same time, there are new opportunities enabled by new technologies, such as self-driving transportation systems, sharing economy, artificial intelligence, digitization, smart buildings and cities, and big data accumulated by information and communication technology (ICT).
- The integration of different knowledge systems, including indigenous and local (traditional) knowledge is one of the

key challenges for many developing countries. Johnson et al. (2016) stressed that 'productive and reciprocal collaboration between indigenous and sustainability science could create a new vision for sustaining resilient landscapes'. Strengthening of the science-policy-society interface and co-production of knowledge, as well as future scenarios with innovative policy options, should be explored to lead effective actions for operationalizing and implementing SDGs from local, national and regional to global scales (Takeuchi et al., 2017).

- The SDGs consist of 17 goals and 169 related targets. Across the goals, 42 targets focus on means of implementation, and the final goal (17), is entirely devoted to means of implementation. However, these implementation targets are largely silent about interlinkages and interdependencies among goals (Stafford-Smith et al., 2017). Actions or measures taken to achieve one goal may be mutually reinforcing or contradictory with respect to achieving other goals. sustainability science is expected to provide useful scientific knowledge to avoid potential trade-offs between different goals and targets, and to maximize synergy among them (Saito et al., 2017).

- The SDGs' fundamental philosophy is 'no one left behind'. How to enhance inclusiveness through the SDG implementation process is also one of the key challenges for sustainability science when evaluating SDG programmes, particularly when capturing the overarching concepts applicable across all 17 goals, such as educational dynamics and resilience (Yonehara et al., 2017).

- The consideration of employment and demographic trends is an important issue when exploring the contribution of sustainability science to global environmental challenges. In 2015, unemployment affected more than 73 million of 1.2 billion youth aged 15–24 years. By 2030 – the target date for the SDGs – the number of youth is projected to have grown by 7%, to nearly 1.3 billion. Although the size of the youth population has peaked in all regions, in Africa the number of youth is growing rapidly. In 2015, the region accounted for 19%; the estimate for 2040 is 42%. Youth can be an extremely positive force in defining alternative and more sustainable models for development, when access to knowledge and opportunities exists. If instead, they are unemployed or underemployed in subsistence agriculture or the informal sector, the growing number of youth will pose a challenge to the achievement of sustainable development, and could cause social or political destabilization (Filmer et al., 2014). Education and research systems should pay special attention to human capacity development and to governance mechanisms that promote broader participation and dissemination of knowledge for the benefit of vulnerable groups such as youth and women.

1.3. UNESCO's contribution to sustainability science

The United Nations Educational, Scientific and Cultural Organization (UNESCO) was created in 1945 to promote a culture of peace – an essential condition for sustainable development. UNESCO recognizes that sustainable development should respond in an integrated and inclusive manner to the complex challenges of today and is capitalizing on its interdisciplinary expertise and intersectoral mandate to support the implementation of the 2030 Agenda with a special focus on developing countries and the African region.

UNESCO's operational strategy for Priority Africa is aligned with the 2030 Agenda for Sustainable Development, which in turn fully integrates the 2063 Agenda of the African Union. Moreover, UNESCO's operational strategy for Priority Africa is in line with Africa's official position for the 2030 Agenda, namely the Common African Position (CAP), which focuses on six pillars: (i) structural economic transformation and inclusive growth; (ii) science, technology and innovation; (iii) people-centred development; (iv) environmental sustainability, natural resources management and disaster risk management; (v) peace and security; and (vi) finance and partnerships, which are all part of the SDGs. This strategic alignment will enable UNESCO to increase the scope of its action in and for Africa, and to improve the commitment of its sectors, institutes and specialized networks, as well as the mobilization of external actors, including strategic and financial partners.

Another global priority for the organization is gender equality and the empowerment of women and girls. Therefore, gender equality is mainstreamed in all UNESCO programmes to support the implementation of the 2030 Agenda. This includes promoting girls' and women's education; promoting women in science and science governance, especially at decision-making levels and in relation to water management; promoting safe access for girls and women to drinking water and adequate sanitation; promoting women as agents of social transformation; promoting the full participation of women in cultural life, promoting women in the media and the empowerment of women through ICTs. All these areas contribute to the implementation of SDG 5. UNESCO also supports countries in mainstreaming gender

equality across all the SDGs, including through the collection of sex-disaggregated data and guidance on advancing gender equality and the empowerment of women in all UNESCO's fields of competence.

By its own interdisciplinary structure, inclusive approach and as the specialist UN agency for Science, Engineering, Technology and Innovation (SETI) cooperation, UNESCO is very well-positioned – with its unique network of multistakeholders – to promote sustainable development, especially in developing countries and in Africa in particular.

Figure 1.1 provides an overview of the contributions of UNESCO to sustainable development.

UNESCO aims to ensure the contribution of the full spectrum of science, technology and innovation to sustainable development, *inter alia,* through:

- Fostering the development of inclusive transdisciplinary STI systems, through the development of institutional capacities to design, implement and evaluate STI policies and policy instruments, including the Global Observatory of STI policy instruments;
- Promoting the development and appropriation of technologies that encourage innovation and youth employment in the production sector, including at grassroots level;
- Providing technical support for the development of institutional and individual capacities in STI and for its exchange through participation in international and global platforms;
- Strengthening the science-policy interface, including through the process of scientific assessments in relation to biodiversity and ecosystem services (IPBES), freshwater, the oceans (IOC), disaster risk reduction, and through co-designed research activities in the area of global change and sustainable development (Future Earth);
- Providing adapted regulatory and ethical frameworks to address science and innovation governance challenges *inter alia* supporting the monitoring and implementation of UNESCO's 2017 Recommendation on Science and Scientific Researchers that supersedes its 1974 Recommendation on the Status of Scientific Researchers;
- Supporting participatory approaches for the mutual engagement of science and society, with a particular view to promoting the equitable involvement and inclusion of women and youth and other vulnerable groups, such as indigenous peoples;
- Promoting transdisciplinary science education curricula and innovative thinking for sustainable development;
- Developing decision-making tools for enhancing the resilience of Member States to deal with climate change and natural hazards, in particular in least developed countries (LDCs) and Small Islands Developing States (SIDS);
- Enhancing future-oriented social science and humanities research on social transformations and intercultural dialogue to strengthen national social science policies and international scientific cooperation;
- Promoting ethics in science and Responsible Research and Innovation (RRI), and providing forums for discussion on new challenges through dedicated ethical national committees and RRI global networks and databases;
- Promoting global scientific advice to UN and national authorities and promoting science diplomacy for peace building;
- Collecting and analysing education and SETI indicators and global trends reports on natural and social sciences and engineering, gender disaggregated, for policy guidance; and
- Supporting scientific excellence and exchange through open access policies and a network of specialized research institutes, category II centres and Chairs around sustainability challenges.

UNESCO leads and relies on delivery mechanisms in the form of international and intergovernmental scientific programmes to:

- Promote knowledge and capacity for protecting and sustainably managing the ocean and coasts;
- Promote global cooperation in the ecological sciences and geological sciences, including through the use of UNESCO designated sites as learning places for sustainable development;
- Promote the conservation of biocultural diversity and the multiple valuations of biodiversity and ecosystem services;
- Improve risk reduction, early warning of natural hazards and disaster preparedness and resilience;

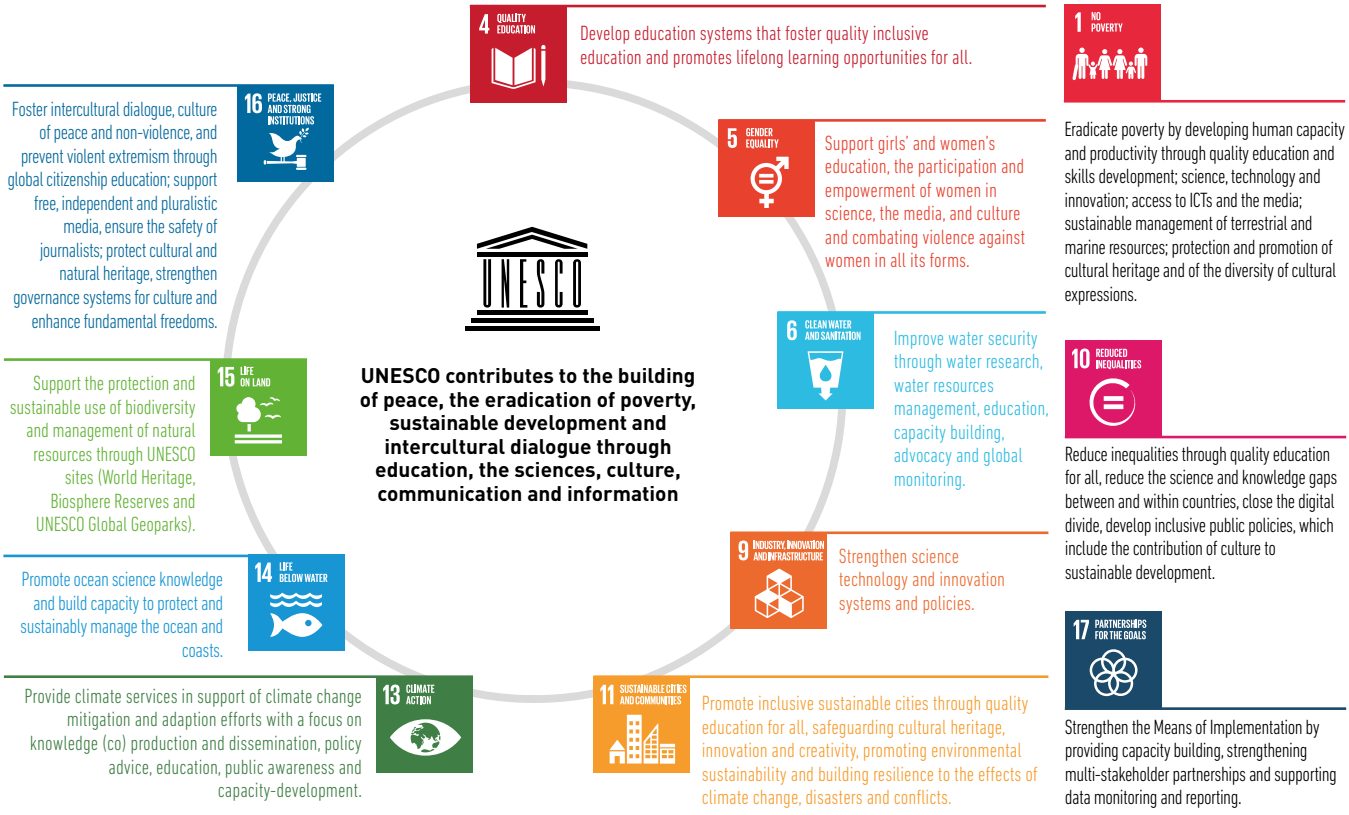

Figure 1.1. Contributions of UNESCO to sustainable development.
Source: UNESCO, 2017

- Foster and strengthen freshwater security and cooperation to exchange and produce knowledge for an improved management of transboundary basins;
- Assist Member States in addressing the social dimensions of peaceful and sustainable development, in particular through the advancement of a society for all in which the benefits of human progress would extend to the most vulnerable segments of society and would contribute to sustainable development, social justice and peace through social transformations founded on ethical and human rights-based approaches; and
- Improve the relevance of education in the face of global sustainability challenges and promote Education for Sustainable Development as a catalyst and enabler for sustainable development.

Capitalizing in this expertise and network, UNESCO has taken the lead in broadening the application of the sustainability science approach to progress the outcomes of the 2012 United Nations Conference on Sustainable Development, held in Rio de Janeiro. Its Member States have identified the need to continue mobilizing the full spectrum of sciences to advance sustainability science in order to address complex and interlinked global challenges in a transdisciplinary way, and to promote the development of related capacities (UNESCO, 2013*a*). UNESCO's Medium-Term Strategy 2014–2021 includes the mainstreaming of the sustainability science approach within UNESCO's own programme and its 195 Member and 10 Associated Member States' development agendas. However, and possibly because of its own diversity, there was a lack of institutional mechanisms to advance the mainstreaming of sustainability science, especially for higher education and research, as well as for the promotion of effective dialogues between research, policy and society.

In October 2015, UNESCO with the support of the Japanese Ministry of Education, Culture, Sports, Science and Technology, initiated the project 'Broadening the application of the sustainability science approach' in order to identify good practices and develop policy guidelines to help Member States develop the education and STI policy instruments required to harness sustainability science's potential to meet the SDGs. The

first two international symposia organized (Paris 2016, Kuala Lumpur 2016) gathered scientists, policy-makers and other relevant experts to explore ways to strengthen the science-policy-society interface and apply the sustainability science approach, taking into consideration region specificities. The Guidelines on Sustainability Science for Research and Higher Education were adopted by UNESCO Member States in June 2017. They contain policy advice on developing normative and structural frameworks for sustainability science, in order to enable the mobilization/interaction of national actors, including indigenous and local knowledge-holders and practitioners (UNESCO, 2017).

Along the same lines, and at the national level, UNESCO, with the support of the Swedish International Development Cooperation Agency (Sida), initiated a project to develop and mobilize the capacities of developing countries to participate in the Future Earth Initiative. The project provided a forum for multiple stakeholder discussion on how to foster integrated, collaborative, interdisciplinary and action-oriented research to address interdependent and complex sustainability challenges in six pilot developing countries: Bolivia, Ethiopia, Kenya, Rwanda, Tanzania and Uganda.

On the basis of the country capacity assessments co-produced in the project, national stakeholders discussed as a priority national sustainability STI agendas and proposed concrete policy instruments that were validated in the form of National Capacity Building Actions Plans. This publication is one of the project outputs and should serve to advance understanding of the sub-Saharan African region's contextual factors, and the learning of lessons in implementing the Guidelines for Sustainability Science in the continent.

Photo 1.2. UNESCO-Sida national workshop for the assessment of national capacities in Tanzania
© UNESCO/J. Chaves-Chaparro

1.4. Aim and scope of the book

Within the sustainability science principles and framework, this book addresses some of the questions and challenges posed above, aiming to analyse what is being done and identify the constraints faced by African countries in implementing the sustainability science approach, in order to draw up policy recommendations for the region.

After providing a general overview of the main sustainability challenges and research efforts in the region, this book describes the steps that five sub-Saharan African countries (Ethiopia, Kenya, Rwanda, Tanzania and Uganda) are taking to develop and strengthen sustainability science. This set of countries includes four out of the five (excluding South Africa) sustainability science regional research hubs (Elsevier and Sci Dev Net, 2015). While describing the countries' efforts to develop sustainability science, this book will not necessarily discuss in detail the key overall issue of policy-based evidence, but will contribute to the extensive discussion on these issues in developing contexts (Göransson et al., 2016).

The selection of countries corresponds on the one hand to those African countries that were included in the UNESCO-Sida cooperation agreement but also, and more importantly, because it concentrates on the less-studied four regional research hubs and Rwanda – where UNESCO had done a previous mapping of R&D capacities (UNESCO, 2015), so that the comparison provides a good framework for analysis of the African region's research contribution to facing sustainability problems.

Although limited, research and innovation capacities exist and the different experiences that have been analysed show that contributions to solving sustainability challenges can have a broad impact at the national, regional and global level if an improved understanding is reached and more focused policy and instruments are co-designed and properly implemented.

1.5. The target countries

The African Economic Outlook (AfDB, 2016) points out that in 2015, the continent continued showing a strong economic performance, with GDP real growth at 3.6%. It was the world's second-fastest growing regional economy after East Asia. The sub-Saharan region (excluding South Africa) grew faster than the continental average, at 4.2%, with East Africa having the strongest growth rate at 6.3%.

On the other hand, while recognizing that growth suffered a sharp deceleration in 2016 due to changing international economic conditions and severe draughts, it also points out that the sub-Saharan region shows resilience and that it will continue growing in 2017, although at a more modest rate of 2.6% (World Bank, 2017). In general, the forecast for the next two years also shows positive signs, depending on the improved recovery of the world economy and a return to higher commodity prices. The World Bank Report also recognizes that a key domestic risk is the lack of implementation of reforms that are needed to maintain durable macroeconomic stability and sustained growth.

The observed economic growth in the countries chosen for the study, as can be seen from **Table 1.1**, can be attributed not only to favourable international conditions but also to prudent macroeconomic policies. In general terms, the economic performance of this group of countries has been outstanding. All have shown growth rates above 5% and up to 10% for a decade. Such growth has been underpinned by heavy public sector-led investments in sectors such as infrastructure and services. Further, amid conditions of improved intraregional trade, the positive demographic dividend shows opportunities to maintain a resilient economy in the mid-term.

In spite of the observed economic growth and positive trends, stronger policies are needed to overcome existing obstacles to produce a more sustained social transformation of sub-Saharan Africa, that is the poorest region in the world and the second in inequalities after Latin America. According ot the Africa SDG index and dashboards report (2018), food security, health, education and access to basic infrastructure are still big challenges, despite the tremendous progress made in many of these areas under the Millennium Development Goals.

Table 1.1. Demography and size of the economy[1]

	Population	Surface area	Population density	Purchasing power parity gross per capita		Gross domestic product per capita	
	millions	km² 000s	people per 'km²	$ billions	$	% growth	% growth
	2015	2015	2015	2015	2015	2015	2015
Ethiopia	99.9	1 104.3	100	162.4	1 630	10.4	7.6
Kenya	47.2	580.4	83	141.1	2 990	5.7	3
Rwanda	11.6	26.3	471	20.7	1 780	8.9	6.2
Tanzania	53.9	947.3	61	136.4	2 610	7	3.7
Uganda	40.1	241.6	200	71.2	1 770	5	1.6
World	7 005.6	134 325.1	57	115 210.6	15 664	2.7	1.5
Sub-Saharan Africa	1 061.1	24 291.1	43	3 609.4	3 589	3	0.3
Low income	641.9	14 471.5	48	1 027.9	1 601	4.6	1.8
Lower-middle income	2 970	23 351.5	128	19 096.6	6 430	5.4	3.9
Upper-middle income	2 560.4	59 651.5	44	40 607.1	15 860	3.3	2.6
High income	1 182.9	36 850.7	34	54 686.9	46 230	2.2	1.6

Source: World Bank database (Accessed on 7 July, 2017.)

The broader SDGs bring out additional challenges for sub-Saharan Africa that require urgent action. Apart from high inequality, these include sustainable urban development (SDG 11) and peace, security and strong institutions (SDG 16). Countries in the region fare much better on sustainable consumption and production (SDG 12), climate change (SDG 13) and terrestrial ecosystems (SDG 15), underscoring that richer countries are responsible for a disproportionate share of environmental pressure relating to these goals. The remaining low scores on Goal 17 highlight that sub-Saharan Africa has significant potential in mobilizing domestic revenue collection (AU, 2017).

Table 1.2 provides the basic indicators for the Human Development Index (combining health, education and income indicators), where it can be observed that all countries have in effect improved the value of the Index but still remain in the lower positions in the world and regional ranking. In this later case the average value for the sub-Saharan region is 0.523.

Environmental challenges also pose critical challenges to economic growth and improved social conditions in the region.

1 Lower-middle income country: Kenya; Low income: Ethiopia, Rwanda, Tanzania and Uganda

The Environmental Performance Index (Hsu et al., 2016) provides a measure on how well countries perform on high-priority environmental issues in two broad policy areas: protection of human health from environmental harm and protection of ecosystems (ecosystem vitality). Within these two policy objectives, the EPI has scored country performance in nine areas, comprising 20 indicators. **Table 1.3** provides the ranking for the countries in this study, all countries having improved their scores in the last ten years.

Table 1.2. Evolution of the Human Development Index (out of 188 countries)

	Evolution of the Human Development Index								Rank 2015	Change in rank	GINI
	1990	2000	2010	2011	2012	2013	2014	2015			
Ethiopia	...	0.283	0.411	0.422	0.427	0.435	0.441	0.448	174	1	33.2
Kenya	0.473	0.447	0.530	0.536	0.542	0.546	0.550	0.555	146	-1	48.5
Rwanda	0.244	0.332	0.464	0.475	0.485	0.488	0.493	0.498	159	4	50.4
Tanzania	0.370	0.391	0.498	0.504	0.513	0.512	0.519	0.531	151	1	37.8
Uganda	0.309	0.396	0.477	0.477	0.478	0.483	0.488	0.493	163	-3	41.0
Very high HD	0.791	0.836	0.876	0.881	0.884	0.887	0.890	0.892			
High HD	0.574	0.637	0.716	0.721	0.728	0.736	0.744	0.746			
Medium HD	0.465	0.525	0.598	0.606	0.613	0.620	0.626	0.631			
Low HD	0.356	0.388	0.476	0.481	0.486	0.490	0.494	0.497			

Sub-Saharan average 2015: 0.523

Source: UNDP, 2016

Table 1.3. Ranking in the Environmental Performance Index (Score 0 to 100) (178 countries)

Rank in 2016	Country	Score	10-year change %
123	Kenya	62.49	25.36
132	Tanzania	58.34	31.19
135	Uganda	57.56	22.13
147	Rwanda	50.34	6.09
163	Ethiopia	45.83	14.75

Source: Hsu et al., 2016

The above-mentioned observed growth has yet to impact more strongly on the competitiveness of the countries. As shown in **Table 1.4**, the Global Competitiveness Index shows weak capacities, but also shows slight improvements from previous years.

Table 1.4. Global Competitiveness Index Ranking (2016–2017) (Score 0 to10) (138 countries)

Rank	Country	Score	Previous rank
52	Rwanda	4.41	58
96	Kenya	3.90	99
109	Ethiopia	3.77	109
113	Uganda	3.69	115
116	Tanzania	3.67	120

Source: WEF, 2016

Along the same lines, the African Innovation Outlook (AIO) (NEPAD, 2014), shows the weaknesses of the existing STI systems in most of the countries in their respective region. In the case of Africa, the former study indicates that most countries have had STI policies in place for some time and several are in the process of developing or reviewing them. UNESCO, through its Global Observatory of Science, Technology and Innovation Policy (GO- SPIN), is now developing a detailed and structured mapping of the existing research and innovation systems in order to facilitate decision-making. In the case of the set of countries comprising the present study, a mapping has already been published for Rwanda (UNESCO, 2015).

Photo 1.3. Community project to improve production and rice taste in Burundi coordinated by the International Rice Research Institute (IRRI).
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With regard to the discussions that will be presented in this book, the AIO appeals to policy-makers to distinguish science and technology from innovation, as they are governed by different systems, and argues that it is the link between them that makes the innovation system work. The results of the innovations surveys conducted under the African Science Technology and Innovation Indicators initiative (ASTII) also indicate that more firms innovate than carry out research, reinforcing the argument for specific policy instruments to address STI.

The Global Innovation Index 2016 (Cornell et al., 2016) also provides a picture as to the state of research and innovation in the countries, confirming the existing weaknesses that were previously mentioned. **Table 1.5** shows the ranking of the countries in this study. It is noted that at least two of the countries (Kenya and Rwanda) occupy a significant rank in their region.

Table 1.5. Ranking of countries in the Global Innovation Index (Score 0–100) (128 countries)

World rank	Country	Score	Regional rank
80	Kenya	30.36	3
83	Rwanda	29.96	4
99	Uganda	27.14	9
105	Tanzania	26.35	11
110	Ethiopia	24.83	14

Source: Cornell University et al., 2016.

1.6. Structure and content of the book

This book is structured as follows: **Chapter 2**, prepared by Yaw Agyeman Boafo, Rodolfo Dam Lam, Denabo Billo Juju and Osamu Saito, presents a general overview of the academic landscape of sustainability science research in Africa and summarizes the challenges and knowledge gaps for sustainable development in Africa. The chapter sets out to examine the current trends and patterns of sustainability research and how they can contribute to addressing sustainable development African challenges through an extensive literature review, a meta-analysis of academic literature and key reports on SDGs. Specifically, the chapter aims to achieve the following objectives:

- Analyse the current state and direction of scientific research and academic studies on sustainable development and sustainability in Africa;
- Identify and discuss the main challenges facing Africa's sustainable development within the framework of SDGs; and
- Discuss the role of sustainability science in order to achieve the implementation and actualization of the SDGs in Africa.

Based on the academic landscape and the analysis of SDG research in Africa, it is apparent that three SDGs – poverty (SDG1), gender equality (SDG5) and climate action (SDG13) – account for 50% of the entire literature landscape over the last 10 years. Literature addressing more than one SDG is increasing. Although currently these studies represent less than 20% of the total published literature, they show a positive trend, growing faster compared to the 6% of the literature landscape.

According to the African Report on the Sustainable Development Goals (AU, 2017), African priorities include: 1) cross-cutting issues such as maintaining peace and security, governance and institutions, financing, capacity-building and technology transfer, and 2) subregional priorities. The chapter also summarizes details of Africa's development priorities and challenges, categorized into the social, economic and environment aspects currently impeding the achievement of these goals.

The results of SDG inter-linkage analysis in Africa show that both the strongest linkages and largest coverage lie within goals related to poverty (SDG 1), gender equality (SDG 5) and climate action (SDG 13), while the weakest linkages and smallest theme coverage lie within goals related to affordable and clean energy (SDG 7) and responsible consumption and production (SDG 12).

Chapter 3 to Chapter 7 constitute the five country studies. Chapter 3 for Ethiopia was prepared by Alma López-Avilés, Seyoum Leta and Wubalem Tadesse; Chapter 4 for Kenya was prepared by Elsie Onsongo, Emmanuel Mutisya and Christopher Shisanya; Chapter 5 for Rwanda was prepared by Theoneste Ntakirutimana, Carlos Aguirre-Bastos and Leon Rugema Mugabo; Chapter 6 for Tanzania was prepared by Athman Mgumia, Karoli Nicholas Njau, Flower E. Msuya and Francis B. Njau; and Chapter 7 for Uganda was prepared by Maxwell Otim Onapa, Steven Sebbale and Carlos Aguirre-Bastos.

The final chapter 8 on the conclusions was prepared by Juliana Chaves-Chaparro, Salvatore Aricò and Carlos Aguirre-Bastos (editors).

Chapter 3 describes the situation in Ethiopia, where the revised National Science, Technology and Innovation Policy – operational since 2010 – places innovation co-production in a central role in order to build competitiveness and turn Ethiopia into a middle-income country by 2025. The policy stresses that 'the integration and cooperation among various stakeholders will be of paramount importance to realize its objectives'. To pursue this

goal and solve the sustainability challenges faced by Ethiopia, it is necessary to broaden the understanding of innovation, not only as an engine for economic growth, but also as a driver for societal well-being and environmental sustainability. The chapter studies how the engagement of multiple stakeholders shapes the innovation process. The case of Ethiopia provides the tools to explore the collective nature of innovation, stressing that it is a co-evolutionary process, resulting from the alignment of technical, social, institutional and organizational dimensions. Thus, the chapter develops insights into coping with inherent tensions across these dimensions that affect the complex innovation process. Such insights include: ideas about demand articulation, institutional support, knowledge and network brokering and capacity-building to improve the innovation process management.

Within the above context, the chapter provides two case studies that highlight the importance of identifying and involving all stakeholders as well as of carrying out a needs assessment before formulating stakeholder engagement to map out specific issues, outline problems, identify conflicts of sustainable resource use and preservation, and propose and implement acceptable solutions. Because of the importance of the business sector involvement in sustainability challenges, the study on Ethiopia analyses the involvement of the private sector through investors and small business creation. Here the co-evolution of innovation and private sector involvement is discussed, as well as governance aspects and the role of regulation for the engagement of the sector.

The discussion is then followed by the identification of a set of actors and indicators of innovation and sustainability. Two case studies support this part of the discussion: 'tannery waste conversion into biogas and reusable water' and the 'Kebena River restauration project'. In both cases the role of the national innovation systems actors can be identified.

The chapter concludes with a substantive analysis on innovation as an engine for economic growth and societal well-being, including a review of knowledge transfer and community engagement, social impacts linked to innovation, society's role in demanding articulation, and a set of proposals for aligning environmental, technical, institutional, organizational and social dimensions.

Chapter 4 analyses the case of Kenya, endeavouring to transition into an industrialized country, where sustainable development is increasingly becoming an area of focus. Following Kenya's adoption of the Sustainable Development Goals, Agenda 2063: The Africa We Want, and the development blueprint known as Vision 2030, local consensus is emerging on the need to adopt long-term perspectives as an appropriate framework for promoting sustainable development, and involving multiple stakeholders in that endeavour.

The chapter argues that, in considering new strategies to tackle the challenge of governance, sustainability science offers a potentially novel approach, providing a variety of pathways for mobilizing existing diverse knowledge systems to generate contextually relevant knowledge in order to address local sustainability challenges. The authors show that, to a large extent, formal science has received much attention from policy-makers and practitioners alike. On the contrary, experiential knowledge from the informal sector and from traditional knowledge systems are relatively overlooked and undervalued and interaction within and across the existing knowledge systems is relatively weak. The authors assert that further progress towards understanding and tackling 'wicked problems' in the local and global context could be achieved by recognizing complementarities across these knowledge systems, while providing new insights for sustainability science.

The chapter examines the status of sustainability science in Kenya by looking at social, economic and environmental sustainability challenges, and highlights legislation, policies and strategies developed to address these challenges. The chapter further discusses the institutional challenges of implementing these policies.

The chapter then maps Kenya's STI policy framework and the underlying national innovation system, and identifies gaps in the system that are inhibiting its potential to address sustainable development. A key gap is that of underdeveloped cooperation within and among existing knowledge systems – across industry systems, between firms, universities and research institutions, and between formal or 'Western' science and indigenous knowledge systems, and even between different locally-specific indigenous knowledge systems.

The authors identify instances where cooperation is being fostered through policy instruments and ad hoc projects, and highlight three illustrative case studies in which a co-designed collaborative interdisciplinary approach to research and innovation was adopted: frugal innovation in weather prediction, education for sustainable development in Africa, and organic agriculture. The chapter concludes by providing some recommendations for policy, research and innovation for sustainable development.

Chapter 5 presents the case of Tanzania, which is one of a handful of African countries that have enjoyed continuous political stability since independence in 1961, and which is providing a more enabling economic context, along with recent anti-corruption

measures. It is also shown that despite the observed economic growth, there are some weaknesses in the social situation, although it is recognized that there has been some success in its poverty reduction strategy and other social reforms.

Several of the economic and social problems in Tanzania come about from environmental challenges that are still to be faced. The country is aware of such challenges, understanding at the same time that problems related to economic and social issues – for example, population growth – also have a large impact on sustainability. The National Environmental Policy identifies six major sustainability problems: 1) loss of wildlife habitats and biodiversity; 2) deforestation; 3) land degradation; 4) deterioration of aquatic systems; 5) lack of accessible, good quality water; and 6) environmental pollution. These are discussed in some detail in the course of the chapter, along with the commitment of the government of Tanzania in addressing sustainability problems, as demonstrated by various initiatives.

This chapter also amply discusses the situation of the national research and innovation system, and policies adopted for its operation. Of particular importance has been the adoption in 1996 of the National S&T Policy, later superseded by a Master Plan adopted in 2002, and refined in 2010. The latter contains a 'Science, Technology and Innovation' policy, geared towards providing a framework through which the linkage, coordination and harmonization of existing and new mechanisms will support other policies and initiatives to achieve the national vision of a middle-income country by the year 2025.

Despite the efforts made during recent years, it is noted that the national research and innovation system of Tanzania is fragmented, and thus has difficulties in responding to the set national policy or S&T objectives as defined in the respective policies. In general, public investment is still low, there is a lack of support for private sector involvement in research, and inadequate mechanisms for technology transfer and the commercialization of research results. In addition, the human resource base is small and Ph.D.-holders at universities have very few funds available to concentrate on research.

The chapter also describes the different efforts that have been made by the national research and innovation system to deal with sustainability problems. It reviews two success stories for co-designed collaborative interdisciplinary sustainability research. The first case is the Chololo Ecovillage project, an initiative with a focus on helping the most vulnerable developing communities to more effectively address the challenges associated with climate change. The second is a project dedicated to the 'Sustainable Management of Waste', that resulted in an innovative process whereby agro waste undergoes a series of treatments, resulting in a biogas, organic fertilizer and clean water for reuse.

Chapter 6 analyses the case of Rwanda, a country facing a number of sustainability challenges, resulting from its increasingly dependent exploitation of natural resources. Biodiversity is being lost or compromised with the disappearance, conversion, fragmentation, pollution or degradation of its natural flora, fauna, and land and water resources. The discussion shows that Rwanda has made important inroads towards sustainable development to face these challenges, due to the establishment of policies and strategies that have created and enabled an environment conducive to the acceleration of social and economic reforms. It also highlights that Rwanda is becoming a hub for sustainable science in Africa through the adoption of several research and technology initiatives, in cooperation with more developed countries.

This chapter goes into some detail in order to highlight the country's efforts towards adopting a number of sustainability-related policies and regulations, including the Rwanda Environmental Policy that was established in 2003. This norm defined the governance mechanisms for managing environmental issues. It created the Rwanda Environment Management Authority and established committees responsible for environmental protection at decentralized levels, i.e. province, district and town. Alongside this, promotion of the green economy is a key foundation to its sustainable development. The Green Economy is enshrined in the National Green Growth and Climate Change Resilience Strategy.

This chapter describes home-grown initiatives that have positively impacted on sustainability. Three case studies are described. The first, *Umuganda* a traditional Rwandan practice and cultural value of working together to solve problems in a shorter time than it would take for an individual to solve them. *Umuganda* embodies the ideas of mutual assistance, mutual social responsibility, social obligation, self-help and traditional strategies for development.

The second case study is that of a community-based health system that covers 9.6 million people. It is paid according to households' *ubudehe* category. The goal of community-based health insurance is to provide Rwandans with equitable and universal access to quality health care.

The third case study is the Vision 2020 Umurenge Programme, a flagship programme of the National Economic Development and Poverty Reduction Strategy (2008–2012), which has a specific focus to accelerate poverty eradication, rural growth and social protection. The main goal of the programme is to eradicate extreme poverty by 2020, from its present level of around 24%.

It is clear, from the discussion around STI policies, home-grown initiatives and traditional values, that besides strengthening and amplifying social development programmes, research needs to be invigorated to respond also to the needs of policy-makers and to emerging challenges requiring more innovation and the development of sustainability science. In fact, the impact of the home-grown initiatives currently being developed could be greatly enhanced within a more ambitious research and innovation system. This can be done partly by policy instruments promoting more inclusive and interdisciplinary STI settings.

Chapter 7 discusses the case of Uganda, examining the extent to which the country has been able to advance its STI agenda and leverage it in the context of sustainability science. The analysis made in this chapter involved an extensive literature review, solicitation of expert opinion and the synthesis of existing knowledge on STI and sustainability science. It also analysed Uganda's STI policy as a tool that can be used to address sustainability challenges. In so doing, it discussed the post-independent STI landscape in Africa as a basis for the emergence of STI policy and policy environment in the country, in particular the SETI policies designed by the different sectors.

Photo 1.4. Traditional fisheries practices
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Uganda has put in place an STI policy with the goal of strengthening the national capability to generate, transfer and apply technologies, and to ensure the sustainable utilization of natural resources for the realization of Uganda's development objectives. The analysis shows, however, that policies still follow a linear model of innovation that focuses on STI actors working in a relational manner of knowledge transfer, without recognizing the complex interactions that exist between these actors within the national STI system. Also, in addition to suffering from a lack of proper coordination geared towards improved and sustainable outcomes, it is noted that the STI policy implementation is beset by weak intersectoral linkages, limited opportunities for firm-level technology absorption and limited sharing of STI learning across the sectors.

The analysis made also shows that, although Uganda has made significant strides towards socio-economic development, the country still lags behind, as illustrated by the low Human Development Index, placing the country in the low human development category. Uganda is also still saddled with a number of sustainability challenges, such as a high population growth rate (which stands at 3.3% per annum), poverty, food and nutrition insecurity as well land degradation, deforestation, biodiversity loss and climate change. It is further reported that Uganda's development framework – Vision 2040, an overarching development framework – is responsive to sustainability and sustainable development.

In an effort to relate innovation efforts in Uganda towards sustainability, three case studies are presented that illustrate the nexus between indigenous knowledge and research addressing sustainability challenges, supported by home-grown funding mechanisms. Based on these analyses, the paper concludes that it is possible for Uganda to harness local knowledge that can promote sustainability science.

Chapter 8 presents the editors' conclusions from a broad analysis of the five country studies, and puts forward a set of common transformation factors and recommendations that should allow the co-design of new approaches to the African mainstreaming of sustainability science through the formulation and implementation of education, research and innovation policies, in line with UNESCO guidelines and the UNESCO Recommendations on Science and Scientific Researchers. In doing so, there is a clear recognition of the importance of capacity-building and intraregional cooperation in harnessing the potential of sustainability science to co-design and co-produce the knowledge and solutions required to address the regional – and global – sustainable development agendas.

References

African Development Bank (AfDB), OECD, UNDP. 2016. *African Economic Outlook 2016: Sustainable Cities and Structural Transformation*. Paris, OECD.

Aguirre-Bastos, C., Aliaga-Lordeman, J., Garrón-Védia, I. and Rubín de Célis Cedro, R. 2016. National innovation system in Bolivia: Making research and innovation matter. B.Göransson, C. Brundenius and C. Aguirre-Bastos (eds). *Innovation Systems for Development: Making Research and Innovation Matter*. Northampton (UK), Edward Elgar Publishing.

Aricò, S. 2014. The contribution of the sciences, technology and innovation to sustainable development. The application of sustainability science from the perspective of UNESCO's experience. *Sustainability Science*, Vol. 9, No. 4, pp. 453–62.

AU. 2017. African Sustainable Development Report: *Tracking Progress in Agenda 2063 and Sustainable Development Goals*. Addis Ababa, African Union, Economic Commission for Africa, African Development Bank, United Nations Development Programme.

Bokova, I. 2012. An integrating policy approach in science, technology and innovation for sustainable development: a UNESCO idea in action. S. Dutta (ed.), *The Global Innovation Index 2012.* Fontainebleau (France), INSEAD and WIPO.

Brundenius, C. and Göransson, B. 2010. The role of the three missions of universities: A synthesis. B. Göransson and C. Brundenius (eds), *Universities in Transition - The Changing Role and Challenges for Academic Institutions.* New York, Springer, pp. 3–10.

Brundenius, C., Lundvall, B.-A. and Sutz, J. 2009*a*. Universities in systems of innovation in developing countries. Towards developmental university systems. C. Chaminade, K. J. Joseph, B-Å. Lundvall and J. Vang (eds). *Handbook of Innovation Systems and Developing Countries*. London, Edward Elgar Publishing.

Brundenius, C., Lundvall, B.-A. and Sutz, J. 2009*b*.Towards inclusive systems of innovation and developmental universities. H. Eggins (ed.). *Sharing Research Agendas on Knowledge Systems*. Occasional Paper No.10. Paris, UNESCO.

Carden, F. 2004. Issues in assessing the policy influence of research. *International Social Science Journal*, Vol. 56, No. 179, pp. 135–51.

Carden, F. 2009. *Knowledge to Policy: Making the Most of Development Research*. New Delhi, SAGE Publications Pvt Ltd.

Clark, W. and Dickson, N. 2003. Sustainability science: The emerging research program. *Proceedings of the National Academy of Sciences of the United States of America,* Vol. 100, No. 14, pp. 8059–61.

Cornell University, INSEAD and WIPO. 2016. *Global Innovation Index 2016*. Ithaca, Fontainebleau and Geneva, WIPO

Court, J. and Young, J. 2006. Bridging research and policy in international development: An analytical and practical framework. *Development in Practice,* Vol.16, No. 1.

Crespi, G. and G. Dutrenit. 2013. *Science, Technology and Innovation Policies for Development: the Latin America Experience*. Heidelberg (Germany), Springer International Publishing.

Dosi, G., Llerna, P. and Labini, M. S. 2005. *Science-Technology-Industry Links and the 'European Paradox' – Some Notes on the Dynamics of S&T Research in Europe*. LEM Working Papers, Series 2005/02. Pisa (Italy), Laboratory of Economics and Management.

Dutrenit, G. and Sutz, J. 2014. *National Innovation Systems, Social Inclusion and Development: the Latin American Experience*. Northampton (UK), Edward Elgar Publishing.

Ejermo, O. and Kander, A. 2006. *The Swedish Paradox*. CIRCLE Working Paper Series, 2006/01. Lund (Sweden), Lund University.

Elsevier and Sci Dev Net. 2015. *Sustainability Science in a Global Landscape*. Retrieved from https://www.elsevier.com/research-intelligence/research-initiatives/sustainability-2015

Filmer, D. and Fox, L. with Brooks, K., Goyal, A., Mengistae, T., Premand, P., Ringold, D., Sharma, S. and Zorya, S. 2014. *Youth Unemployment in Sub-Saharan Africa*. Agence Française/World Development Bank.

Global Forum for Health Research (GFHR). 2004. *The 10/90 Report on Health Research 2003–2004*. Geneva, Global Forum for Health Research.

Göransson, B. and Brundenius, C. (eds). 2010. *Universities in Transition – The Changing Role and Challenges for Academic Institutions.* New York, Springer.

Göransson, B., Toumaala, R. and Ågren, J. 2008. *Women Scientists in Gender-Specific Technological R&D*. http://www.fpi.lu.se/en/research/wosister

Göransson, B., Brundenius, C. and Aguirre-Bastos, C. (eds). 2016. *Innovation Systems for Development: Making Research and Innovation Matter*. Northampton (UK), Edward Elgar Publishing.

Hsu, A., Emerson, J., Levy, M., de Sherbinin, A., Johnson, L., Malik, O., Schwartz, J. and Jaiteh, M. 2016. *The 2016 Environmental Performance Index.* New Haven, CT, Yale Centre for Environmental Law and Policy. Available at: www.epi.yale.edu.

Huyer, S. 2015. *Is the Gender Gap Narrowing in Science and Engineering?* Available at: http://unesdoc.unesco.org/images/0023/002354/235406e.pdf%5Cnhttp://unesdoc.unesco.org/images/0023/002354/235407e.pdf.

Hy, R. J., Venhaus, M. and Sims, R. G. 1995. Academics in service to the legislature: Legislative utilization of college and university faculty and staff. *Public Administration Review,* Vol. 55, No. 5, pp. 468–74.

IAP. 2000. *Statement on Transition to Sustainability.* Tokyo, InterAcademy Panel (now InterAcademy Partnership).

IDRC. 2002. *Closing the Loop - Communication for change at IDRC*. Available at: https://idl-bnc.idrc.ca/dspace/bitstream/10625/21181/1/117024.pdf

Jacobsson, S. and Granberg, A. 2006. Myth and reality – A scrutiny of dominant beliefs in the Swedish science policy debate. *Science and Public Policy,* June.

Jefferys, M., Troy, K., Slawik, N. and Lightfoot, E. 2007. *Issues in Bridging the Divide between Policymakers and Researchers*. Minnesota, MN, University of Minnesota. Available at http://cascw.umn.edu/wp-content/uploads/2014/07/BridgingDivide-PolicyResearch.pdf

Johnson, T. J, Howitt, R., Cajete, G. Berkes, F., Paulani Louis, R. and Kliskey, A. 2016. Weaving indigenous and sustainability sciences to diversify our methods, *Sustainability Science*, Vol. 11, No. 1, pp. 1–11

Kates, R. W., Clark, W. C., Corell, R. et al. 2001. Sustainability science, *Science*, Vol. 292, No. 5517, pp. 641–42.

Komiyama H., Takeuchi, K. 2006. Sustainability science: Building a new discipline. *Sustainability Science*, Vol.1, pp. 1–6.

Lang, D. J., Wiek, A., Bergmann, M., Martens, P., Moll, P., Swilling, M., Thomas, C. J. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science*, Vol. 7(S1), pp.25–43. Available at: http://link.springer.com/10.1007/s11625-011-0149-x [Accessed March 28, 2017].

Liu, J., Hull, V., Batistella, M., DeFries, R. et al. 2013. Framing sustainability in a telecoupled world. *Ecology and Society*, Vol. 18, No. 2, p. 26.

Lundvall, B. A., Joseph, K. J., Chaminade, C. and Vang, J. 2009. Innovation systems and developing countries – an introduction. A. Lundvall, K. J. Joseph, C. Chaminade and J. Vang (eds), *Innovation Systems and Developing Countries – Building Domestic Capabilities in a Global Setting*. Cheltenham (UK), Edward Elgar Publishing.

Mazzucato, M. 2013. *The Entrepreneurial State. Debunking Public vs. Private Sector Myths*. London, Anthem Press.

Moravcsik, Michael. 1966. Some practical suggestions for the improvement of science in developing countries. *Minerva*, Vol. 4, pp. 381–90.

NEPAD Planning and Coordinating Agency (NPCA). 2014. *African Innovation Outlook 2014*. Pretoria, NPCA.

Paus, E. 2013. Getting development right. E. Paus (ed.), *Getting Development Right*. New York, Palgrave Macmillan.

Pellini, A., Anderson, J. H, Huong Thi Lan Tran and Irvine, R. 2012. *Assessing the Policy Influence of Research: A case study of governance research in Viet Nam*. Overseas Development Institute, Background Notes. https://www.odi.org/publications/6597-assessing-policy-influence-governance-research-viet-nam-vdr-2010

Piketty, T. 2014. *Capital in the Twenty-First Century*. Cambridge, MA, Harvard University Press.

Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurung, G. S., Schneider, F., Speranza, C. I., Kiteme, B., Boillat, S., Serrano, E., Hadorn, G. H. and Wiesmann, U. 2010. Researchers' roles in knowledge co-production: experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Science and Public Policy*, Vol. 37, No. 4, pp. 267–81.

Ruiz-Mallén, I. and Corbera, E. 2013. Community-based conservation and traditional ecological knowledge: implications for social-ecological resilience. *Ecology and Society*, Vol. 18, No. 4, p. 12. http://dx.doi.org/10.5751/ES-05867-180412

Sachs, J., Schmidt-Traub, G., Kroll, C., Durand-Delacre, D. and Teksoz, K. 2017. *SDG Index and Dashboards Report 2017*. New York, Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN). http://www.sdgindex.org/assets/files/2017/2017-SDG-Index-and-Dashboards-Report--full.pdf

Saito, O., Managi, S., Kanie, N., Kauffman, J. and Takeuchi, K. 2017. Sustainability science and implementing the sustainable development goals. *Sustainability Science*, Vol. 12, No. 6, pp. 907–10. DOI 10.1007/s11625-017-0486-5

Schott, J. and Steinmueller, E. 2017. *Framing Innovation Policy for Transformative Change: Innovation Policy 3.0*. www.johanschot.com/publications

Stafford-Smith, M., Griggs, D., Gaffney, O., Ullah, F., Reyers, B., Kanie, N., Stigson, B., Shrivastava, P., Leach, M. and O'Connell, D. 2017. Integration: the key to implementing the Sustainable Development Goals. *Sustainability Science*, Vol. 12, No. 6, pp. 911–19.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L., Veerabhdran Ramanathan, Reyers and B. Sörlin, S. 2015. Planetary boundaries: Guiding human development on a changing planet. *Science*, Vol. 347, No. 6223, p.1259855. Available at: http://science.sciencemag.org/content/347/6223/1259855.abstract (Accessed January 16, 2015).

Surr, M. A., Barnett, A., Duncan, A. and Spreight, M. 2002. *Research for Poverty Reduction*. DFID Research Policy Paper. London, DFID.

SPP. 2009. *Science and Public Policy*, Vol. 36, No. 2. Special issue on the Third Mission of Universities.

Start, D. and Hovland, I. 2004. *Tools for Policy Impact: A Handbook for Researchers*. London, Overseas Development Institute.

Takeuchi, K., Saito, O., Lahoti, S. and Gondor, D. 2017. Growing Up: 10 years of publishing sustainability science research. *Sustainability Science*, Vol. 12, No. 6.

Toledo Manzur, V. M. 2003. Community conservation and ethno ecology: The three dimensions of local-level maintenance. L. Porter-Bolland, I. Ruiz- Mallén, C. Camacho-Benavides, S. McCandless (eds), *Community Action for Conservation Mexican Experiences*. New York, Springer

UNDP. 2016. *Human Development Report 2016: Human Development for Everyone*. New York, United Nations Development Programme.

UNESCO. 2013*a*. Symposium on Sustainability Science: Promoting Integration and Cooperation, 19 September.

UNESCO. 2013*b*. UNESCO Executive Board Document 192 EX/16, part IV version. 8 August.

UNESCO. 2015. Mapping research and innovation in the Republic of Rwanda. A. Lemarchand and A. Tash (eds), *GO→SPIN Country Profiles in Science, Technology and Innovation Policy,* Vol. 4. Paris, UNESCO.

UNESCO. 2017*a*. *Guidelines on Sustainability Science in Research and Education*, Paris, UNESCO. http://unesdoc.unesco.org/images/0026/002606/260600E.pdf

UNESCO. 2017*b*. *Moving toward the 2030 Agenda for Sustainable Development*. Paris, UNESCO. http://unesdoc.unesco.org/images/0024/002477/247785e.pdf

United Nations. 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. https://sustainabledevelopment.un.org/post2015/transformingourworld/publication. (Accessed 14 October, 2017.)

Willmott, H. 2014. Science, governance and self-understanding: From anthropocentricism to ecocentrism? *Critical Policy Studies*, Vol. 8, No. 1 pp. 22–40.

Wittmayer, J. M. and Schäpke, N. 2014. Action, research and participation: roles of researchers in sustainability transitions. *Sustainability Science*, Vol. 9, No. 4, pp. 483–96. Available at: http://link.springer.com/article/10.1007/s11625-014-0258-4/fulltext.html.

World Bank. 2017. *Global Economic Prospects: A Fragile Recovery.* World Bank Group Flagship Report, June. Washington D.C., World Bank.

World Economic Forum. 2016. *World Competitiveness Report.* Geneva, World Economic Forum.

Yonehara, A., Saito, O., Hayashi, K., Nagao M., Yanagisawa, R. and Matsuyama, K. 2017. The role of evaluation for achieving the SDGs. *Sustainability Science*, Vol. 12, No. 6, pp. 969–73.


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The role of sustainability science in addressing Africa's sustainable development challenges and priorities: A bibliometric survey

2. The role of sustainability science in addressing Africa's sustainable development challenges and priorities: A bibliometric survey

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2.1. Introduction

The growth in the scale of human activity over the last two centuries has resulted in multiple and closely related challenges, including food insecurity, poverty, increasing inequality, limited access to basic needs like water, energy and sanitation, climate change, biodiversity loss and ecosystem services degradation (ECA, 2013; Gasparatos et al., 2017). These challenges not only threaten peoples' social and economic well-being, but also the planet's ecological integrity. In response, global reflections and multilateral efforts, from the World Commission on Environment and Development Conference in 1987 to the 2015 United Nations Sustainable Development Goals (SDGs), reaffirm the commitment of the international community to the pursuit of sustainable development, while at the same time offering a contribution framework for scientists and development practitioners. These multilateral efforts and agreements, coupled with several scholarly analyses, emphasize the need for humans to transform and shift from the 'business-as-usual' approach to development as a way to bridge the increasing disconnect between themselves and the natural world (UNEP-WCMC, 2011; Jaeger et al., 2011).

With the growth in political and scientific interest addressing the current development dilemma facing humans, sustainability science has emerged as a forerunner in the efforts to find a solution. As a collaborative research field, sustainability scholars (Komiyama and Takeuchi, 2006; Kates and Dasgupta, 2007; Kajikawa, 2008; Kates, 2011; Lang et al., 2012) continue to promote sustainability science as having the potential to contribute to finding pragmatic and relevant solutions to complex sustainability problems. In fact, transformative research is currently being undertaken as to how sustainability science can provide both the theoretical and empirical foundation for addressing sustainable development challenges facing both developed and developing countries (Burns and Weaver, 2008; Takeuchi and Obijiofor, 2011; Dedeurwaerdere, 2013; Gasparatos et al., 2017).

Even with the significant economic growth that has led to improved socio-economic conditions for many since the turn of the twenty-first century, Africa as a continent is burdened with multiple and interrelated sustainability challenges. Persistent poverty and inequality, population growth and urbanization, climate change (IPCC, 2014), biodiversity decline and ecosystem services degradation, environmental pollution (Oteng-Ababio et al., 2013), youth unemployment, migration, decline in agricultural production and food insecurity (Sasson, 2012; FAO, 2017), inadequate and underdeveloped energy systems (IEA,[1] 2014), political instability and poor physical infrastructure (Kakonge, 2012) all hinder development efforts across countries.

The scale and priorities of Africa's development challenges vary considerably across the five subregions – North, West, Central, Eastern and Southern Africa (IPCC, 2014). For example, core sustainability challenges in Africa such as climate change and variability and decline in biodiversity status affect all locations of the continent and require urgent, participatory, innovative and transformative action (Mathai, 2011; Niang et al., 2014). To this end, an understanding of the degree to which collaborative and innovative scientific research efforts fit with the actual sustainable development priorities of the continent is imperative.

This chapter attempts to contribute to the growing body of analysis on the theoretical and empirical underpinnings of sustainability science, and of its impact on the sustainable development priorities of Africa. In order to achieve this, the chapter presents the results of a comprehensive bibliometric review and an analysis of the scientific, secondary, tertiary and grey literature on sustainability science research, sustainable development priorities and challenges through the lens of the 17 Global SDGs. Specifically, this chapter aims at to achieve these two interrelated objectives:

1. Present an analysis of current trends, patterns and linkages of collaborative scientific research, academic studies and publications on sustainable development and sustainability focusing specifically on Africa;
2. Evaluate the degree to which ongoing collaborative scientific research, academic studies and publication efforts meet Africa's sustainable development priorities and challenges, with a special focus on gender issues.

2.2. Study methods and data sources

This study is based on a desktop synthesis of existing data and information relating to the theory and practice of sustainability science and sustainable development in Africa. Bibliometric studies constitute an effective methodology for analysing broad research data and gaining a thorough understanding of trends and patterns (Kajikawa et al., 2007; Bettencourt and Kaur, 2011; Kajikawa et al., 2014).

1 International Energy Agency

The literature landscape – combining scholarly journal articles and grey literature over the last ten years – was analysed in order to understand how the research and scientific community, as well as national and international development organizations, are addressing Africa's sustainability challenges. A content analysis of peer-reviewed publications identified common research topics and compared them against Africa's sustainable development priorities, as identified by the African Union Commission and the World Bank Atlas.[2] Based on a content analysis of the collected literature, key themes and views could then be identified to assess Africa's challenges.

2.2.1. Literature landscape collection

A combination of both academic (Scopus) and policy-relevant (African Union Commission, World Bank Atlas) sources were consulted for the systematic literature review on Africa's sustainable development challenges:

a) **Scopus:** Scopus is the world's largest abstract and citation database of peer-reviewed research literature. We collected academic literature related to each SDG in Africa for the last ten years. This bibliographic database was selected as the preferred literature search engine, given its extensive journal coverage, transdisciplinary orientation and accurate results (Harzing and Alakangas, 2016; Mongeon and Paul-Hus, 2016; Adriaanse and Rensleigh, 2013).

b) **African Union Commission (2015):** Prior to the adoption of the SDGs by the UN, the African Union Commission (AUC) prepared a continental 50-year agenda through a people-driven process, outlining 'The Africa We Want', namely Agenda 2063. After the adoption of the Agenda 2063 Framework Document in January 2015, the AUC developed the First Ten Year Implementation Plan of Agenda 2063 (2013–2023).[3]

c) **World Bank Atlas:** The Atlas is an open knowledge repository, which provides a comprehensive visual guide to the most critical issues facing the world.[4] The Atlas of Sustainable Development Goals 2017 was used to identify issues and priorities for SDG implementation in Africa.

The Scopus systematic literature review collected research relevant to each SDG conducted in Africa. A set of keywords were selected for each SDG (see **Appendix 2.1**), based on their descriptions, to conduct a search pattern in Scopus. A total of 17 search patterns were performed to identify the literature coverage for each individual SDG. The results were further filtered to show the publications from the last 10 years (from 2008 until July 2017),[5] capturing the outcomes of the academic research landscape from halfway through the MDG implementation until the early years of the SDG coming into force. A composed keyword search function in Scopus was used to capture words within a distance of five words from each other.[6] All 17 search patterns included 'Africa' as a mandatory match, plus at least one keyword related to the SDG. The search looked at the publication's title, abstract and author's keywords. Highly specialized medical publications were excluded from the results using Scopus subject area filters (i.e. genetics and molecular biology), given the focus of these applied sciences in specific areas exploring practical applications of existing knowledge, rather than holistic sustainability challenges. A total of 30,407 unique literature documents were collected through this search method and will hereafter be referred as the 'literature collection'.

2.2.2. Content analysis

The content in the abstract, title and keywords for peer-reviewed articles, books, and book chapters found in Scopus was analysed through the following two stages in order to capture a snapshot of ongoing study trends within the research community.

The first stage used NVivo's word frequency analyser to search for the number of times a word appears over the entire content found in each SDG literature collection. The NVivo software, developed by QSR International, was selected since it is able to analyse large quantities of data through its automated functions. The main advantage of automated coding over manual is that it avoids inconsistencies related to coders' bias and human error due to fatigue (Bengtsson, 2016; Neuendorf, 2016). In order to achieve a better balance between consistency and accuracy in the results, a word grouping was used to include stemmed words, allowing words with slide variations (e.g. 'sustainable', 'sustainability') between SDG literature collections to be identified as the same theme, hence ensuring a higher consistency between collections. While NVivo has

2 Available at https://blogs.worldbank.org/opendata/2017-atlas-sustainable-development-goals-new-visual-guide-data-and-development

3 Available at http://www.un.org/en/africa/osaa/pdf/au/agenda2063-first10yearimplementation.pdf

4 Available at https://openknowledge.worldbank.org/handle/10986/2175

5 July 2017 was the latest information available at the moment of the analysis

6 i.e. 'clean, cheap, and efficient energy' match a search looking for 'clean' and 'energy'

the ability to group words at higher generalization levels to include synonyms, tests with this feature proved to provide inappropriate interpretations of the grouping (e.g. 'challenges', 'dispute', 'competition'). Therefore, words were only grouped at their stem level (e.g. 'challenges', 'challenging' and 'challenged' into 'challenge'). Given the intricacies of the diverse study fields, the results of themes using this synonym feature would have adversely affected the accuracy of the analysis.

The second stage of the methodology involved a manual verification of the top 30 keywords within each SDG. This revision solved minor inconsistencies between SDG collections (e.g. 'challenge', 'challenges', 'challenging'); the removal of stop words (e.g. 'percent', 'among', 'rate', etc.) not included on the default list (e.g. 'the', 'and', 'in', etc.); and the removal of proper nouns (e.g. 'Africa', 'South', etc.).

Finally, the same method to identify trending themes for each SDG literature collection was applied to documents collected from the African Union Commission and the World Bank Atlas by SDGs.

As a result, a word cloud (see **Appendix 2.4**) for each SDG was created, combining the results from all literature sources used. The relative size of each word denotes the importance of the word as a trending theme, while the grouping of such trending themes expresses an overarching theme for each of the SDGs. This view allows us to identify the research focus and frame each SDG under a general context for subsequent analysis.

In addition, a list of the top three trending themes by SDG was selected for the academic and policy-relevant sources, i.e. Scopus, the African Union Commission (2015) and the World Bank Atlas. The outcome of this list is a set of themes for each SDG, ranging from three (where all three themes are the same across each literature source) to nine (where all three themes are different across each literature source). The results identified a total of 89 different themes among all 17 SDGs across the three literature sources. This list was subsequently mapped in a matrix for each SDG, comparing the themes on the one hand and the literature sources on the other, which indicates the key concerns of each literature source and whether the research community is addressing the region's priorities.

Similarly, online searches were conducted to retrieve literature related to the sustainable development priorities and challenges in Africa by using combinations of keywords like 'sustainability or sustainable development' AND 'Africa or African', 'sustainability challenges or constraint or problem' AND 'Africa or African'. Reports from organizations such as the African Union, United Nations' agencies and the World Bank Atlas of Sustainable Development Goals were used. The challenges identified were classified under social, economic and environmental categories (see **Table 2.1**), following the 2015 report by the United Nations Economic Commission for Africa.

2.2.3. Interlinkage analysis

It is of key importance to understand the interconnections between SDGs in order to successfully implement their targets. As such, multiple studies have developed frameworks to capture potential synergies and trade-offs between SDG targets (ICSU, 2017; Ntona and Morgera, 2017; Singh et al., 2017). Therefore, it is also important to appreciate the linkages between SDGs in the literature in addressing Africa's development challenges.

Interlinkages across SDGs were mapped, based on theme connection. The list of 89 themes generated from the top three trending themes served as input to assess SDGs' linkages. An arc diagram with three layers of information was subsequently developed. The diagram shows the connection strength between each possible pair of SDGs based on the sum of each theme connection frequency, estimated as the lowest frequency value for the same theme between the pair of SDGs. **Equation 1** shows the function used to estimate the link strength 'α' between two SDGs where 'S' represents the first SDG to be analysed, 'S1' the second SDG to be analysed, and 'i' the frequency of each top trending theme. The second layer of information conveys the relative coverage of each SDG across the themes represented by the size of the label and measured by the sum of all 'α' from each possible pair of connections for the given SDG. The final layer of information is delivered as a list of the top five highest connections and the top five weakest connections across all possible pairs of SDGs. Four arc diagrams were produced, one for each literature source, and a consolidated diagram grouping all three sources provides an equal weight for each. The image produced identifies interlinkages between SDGs and highlights possible synergies and trade-offs between these connections (ICSU, 2017) (see **Appendices 5–7**).

$$\alpha = \sum_{i=1}^{89} \min\left(S_i, S_{1i}\right) \quad (1)$$

Equation 2.1. Function used to estimate the link strength between two SDGs.

The fourth and last image shows the highest level of detail between themes and SDGs. The top five trending themes for each literature source and their connections to each SDG were mapped in a chord diagram (see section 2.6 of this chapter). The

link to each SDG of each theme combined with its frequency was the main input for the diagram. There are two levels of information provided with this view that explain in detail how the SDGs are linked. Firstly, it shows through which themes the interlinkages between SDGs occur and secondly, the relative strength of such connections, allowing us to identify key themes for Africa's development challenges and how they address issues identified on policy-relevant sources.

Notwithstanding this study's heavy reliance on credible peer-reviewed and grey literature to form a broad scientific database, findings should be interpreted with care and should not be generalized. We acknowledge the limitations of not capturing important data on the issues under consideration in this study. In reality, there exist several national – and local – level initiatives, innovations and capacity-development actions aimed at promoting a better understanding and implementation of the 17 SDGs, with the goal of solving Africa's sustainability challenges. Data for these intervention strategies may not be readily accessible in any of the online databases accessed for this study.

2.3. Results and discussion

2.3.1. Contextualizing Africa's sustainable development challenges

According to the African Sustainable Development Report (AU, 2015), African priorities include: 1) cross-cutting issues like maintaining peace and security, governance and institutions, financing, capacity building and technology transfer, and 2) subregional priorities. However, the implementation of those targets involves enormous challenges such as population growth, shortage of finance, and poor technical and human capacities (FAO, 2017; Jaiyesimi, 2016). About half of the expected population growth until 2050 will occur in Africa (UNDESA,[7] 2017). With the world's highest growth rate of 2.44%, the African population will double every 28 years (Primorac, 2016).Moreover, climate change and related environmental problems like land degradation, desertification, deforestation and pollution are also increasing (Whitfield, 2016).

Table 2.1. African sustainable development priorities and potential challenges

African sustainable development priority issues	Related SDG(s)
Maintaining peace and security	SDG-16
Ensuring good governance and building strong institutions	SDG-17
Sustainable financing	SDG-17 (all)
Human capacity development	SDG-17 (all)
Foster technology transfer	SDG-17
Combating climate change	SDG-13
Mitigating environmental problems	SDG-14, 15
Economic growth	SDG-1, 8, 10
Improving quality of education	SDG-4
Creating employment opportunities	SDG-8, 10
Ensuring food security	SDG-2, 3
Energy development	SDG-7, 3, 15
Reducing gender inequality	SDG-5
Reducing poverty	SDG-1, 10
Improving health and nutrition	SDG-3
Water management and sanitation	SDG-6, 3
Transport and infrastructure	SDG-11, 9
Agricultural productivity	SDG-2, 1
Urban management and sanitation	SDG-11, 12, 3

Source: United Nations Economic Commission for Africa, 2015; World Bank Atlas of Sustainable Development Goals. 2017

7 United Nations Department for Economic and Social Affairs

Regions in Africa					Category	Challenges
Northern Africa	Eastern Africa	Southern Africa	Central Africa	Western Africa		
√[1]	√	√	√	√	Social	Low political commitment, fraudulent elections, resource-based conflicts, etc.
√	√	√	√	√	Social	Low political commitment, weak institutions, corruption, limited human capacities and poor public service
√	√	√	√	√	Economic	Poor capacities to mobilize domestic resources, high dependency on foreign funds and corruption
√	√	√	√	√	Economic	Shortage of finance, lack of standard facilities and expertise
√	√	√	√	√	Economic	Weak commitment from recipient and supporting countries, poor facilities and lack of funds
√	√	√	√	√	Environmental	Lack of reliable data, poor financial and technical capacities
√	√	√	√	√	Environmental	Lack of reliable data, poor financial and technical capacities
√	√		√	√	Economic	High dependency on primary goods and low-value addition
√	√	√	√	√	Social	Maintaining quality of education while increasing its coverage
√	√	√	√	√	Economic and social	Coping with rapidly growing young work force and equipping the youth with appropriate skills
√	√	√	√	√	Economic	Climate change, poor investment in agriculture, population growth and restrictive policies
√	√	√	√	√	Economic	High dependency on fossil fuel, lack of technical and financial capacities to develop renewable energies
√	√	√	√	√	Social	Low commitment to empowering women and institutional constraints
√	√	√	√	√	Social	Poor economic performance, lack of political commitment and population growth
√	√	√	√	√	Economic	Lack of finance, shortage of skilled personnel and poor health facilities or infrastructure
√	√	√	√	√	Social	Poor infrastructure, inadequate finance, pollution, over-abstraction and receding ground water (e.g. drought)
√	√	√	√	√	Economic	Inadequate technical, financial and human capacities
√	√	√	√	√	Economic	Climate change, poor extension and low investment in agriculture
√	√	√	√	√	Social	Fast urban population growth, inadequate technical, financial and human capacities

Social challenges

SDG 1: No poverty – Poverty has decreased in some parts of Africa, while it is increasing in others (see **Figure 2.1**). It has decreased in countries like Tanzania where strong institutions and prudent macroeconomic policies exist along with political stability and low-income inequality (Handley et al., 2009). Nevertheless, it has increased in other countries (e.g. Zambia) due to lack of good governance and prevalence of clientelism, rampant corruption and high-income inequality (Handley et al., 2009). Overall, the average subregional poverty rates are still high. For instance, they stand at 47.5% in Eastern Africa, 45% in Southern Africa and 55% in Central Africa (UNECA, 2015*a*). Despite remarkable progress, in some regions of the continent, over 40% of the African population still live in abject poverty (UNECA, 2015*a*) and sub-Saharan Africa currently accounts for half of the world´s extreme poverty (World Bank, 2017). Rural residents in Africa have a higher rate of poverty than urban dwellers, though the gap between urban and rural poverty has reduced from 35% in 1996 to 28% in 2012 (Beegle et al., 2016).

Among its regions, West Africa has reduced urban poverty by half and rural poverty by 40%. The poverty reduction in West Africa can be atributed to the long-term economic growth that has happened in some countries in the region, such as Ghana and Senegal (Wodon, 2007; Molini and Paci, 2015); the decrease in income inequality, mainly in countries whose economies depend on agriculture (Ayodele Odusola et al., 2017); and the low proportion (just 15%) of female-headed households (Beegle et al., 2016). According to these authors, the low number of female-headed households is due to the higher tendency of re-marriage and polygamy, and the fact that female-headed households are more likely to be poor.

SDG 2: Zero hunger – Food insecurity remains a major challenge in Africa. Population growth, climate change and a declining economy are worsening food insecurity in the continent (FAO, 2017). About 26% of sub-Saharan Africa's population was food insecure in 2014/2015 (World Bank, 2017). Moreover, Africa accounts for a quarter of the undernourished population in the world. According to the Global Hunger Index (IFPRI, 2017), Africa's regional scores are very high, i.e. Sahel region (33.50), Eastern Africa (29.7), Great Lakes region (27.7), Southern Africa (27.5) and West Africa (26) (AfDB,[8] OECD and UNDP, 2017).

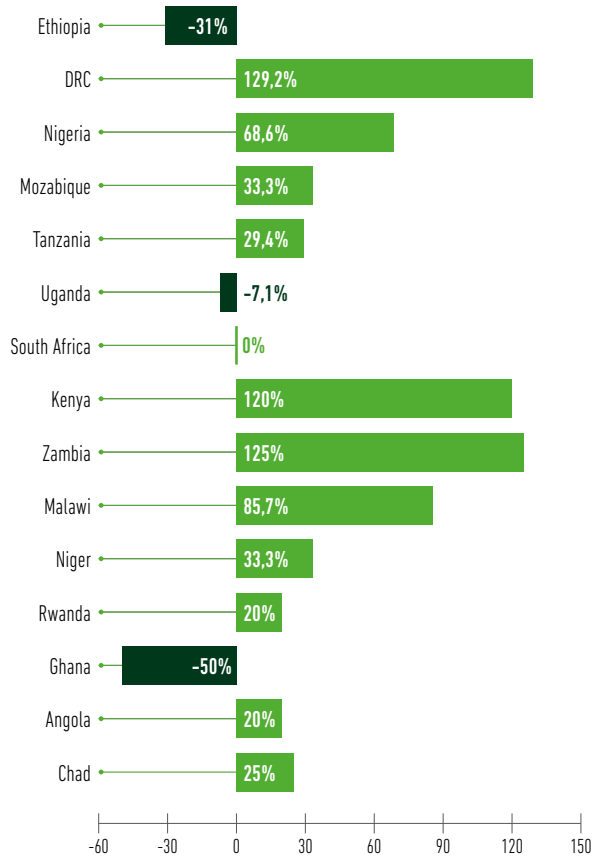

Figure 2.1. Poverty change from 1990 to 2013.
Source: World Bank Atlas of Sustainable Development Goals, 2017.

SDG 3: Good health and well-being – Child mortality in Africa is declining. For instance, it dropped to 83 deaths per 1,000 live births in 2015, down from from 180 deaths per 1,000 live births in 1990 (UNECA, 2015*a*). The continent has also made significant progress in life expectancy (see **Figure 2.3**). Life expectancy has increased from 52 years in 1990 to 72 years in North Africa, and 57 years in the remaining subregions in 2010 (JICA,[9] 2013). The report noted that the increase in life expectancy in North Africa was due to improved access to health care, clean drinking water and sanitation services. According to the same source, until 2011, the proportion of the population with no access to clean water and sanitation was 10% in North Africa and 70% in sub-Saharan Africa. However, life expectancy has declined in some countries like South Africa and Zimbabwe, mainly due to HIV/AIDS (World Bank, 2017). Africa in general and the sub-Saharan region, in particular, has the highest rate of death from communicable diseases such as HIV and tuberculosis. For

8 African Development Bank

9 Japan International Cooperation Agency

instance, in 2015 there were 276 new tuberculosis cases for every 100,000 people and 3 people in every 1,000 had contracted HIV/AIDS (World Bank, 2017).

There is still high gender inequality in the prevalence and risk of contracting HIV/AIDS in sub-Saharan Africa. For example, Sia et al. (2016) reported gender inequalities in HIV/AIDS in the range of 0.68% in Liberia and 11.5% in Swaziland, due to various factors such as age difference at the onset of sexual activity (women tend to be younger than their male counterparts), women's limited control over resources (which means they are less able to protect themselves), and marital status (differential social status forces women to engage and stay in sometimes abusive marriages). The rate of premature deaths from major non-communicable diseases – cardiovascular, cancer, diabetes and chronic respiratory illness – in Africa is also increasing and has grown to over 25% in a few countries, such as Sudan and South Africa (World Bank, 2017). Zimbabwe has launched an exemplary scheme called 'Talk-Surf and Save a Life' which imposes a 5-cent health fund on mobile users for every dollar of airtime used, in order to solve financial challenges facing the health sector and improve access to healthcare (UNDESA, 2018).

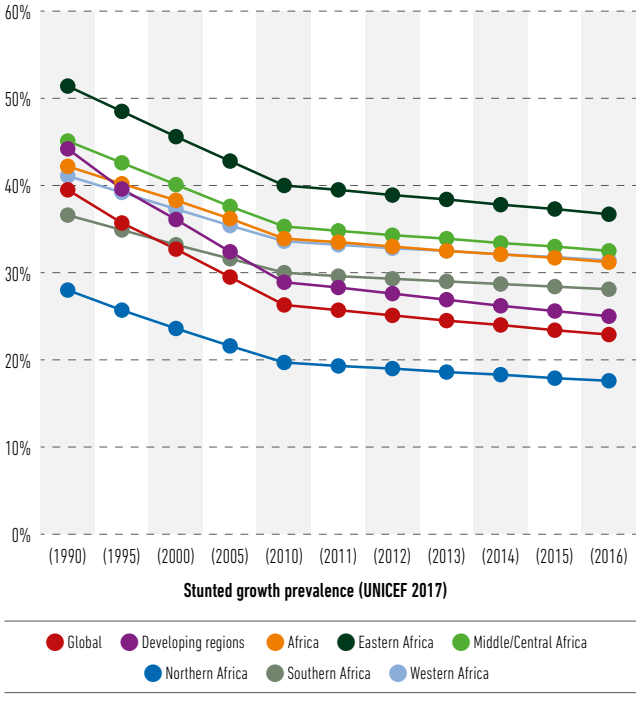

Figure 2.2. Stunted growth prevalence.
Source: UNICEF, 2017.

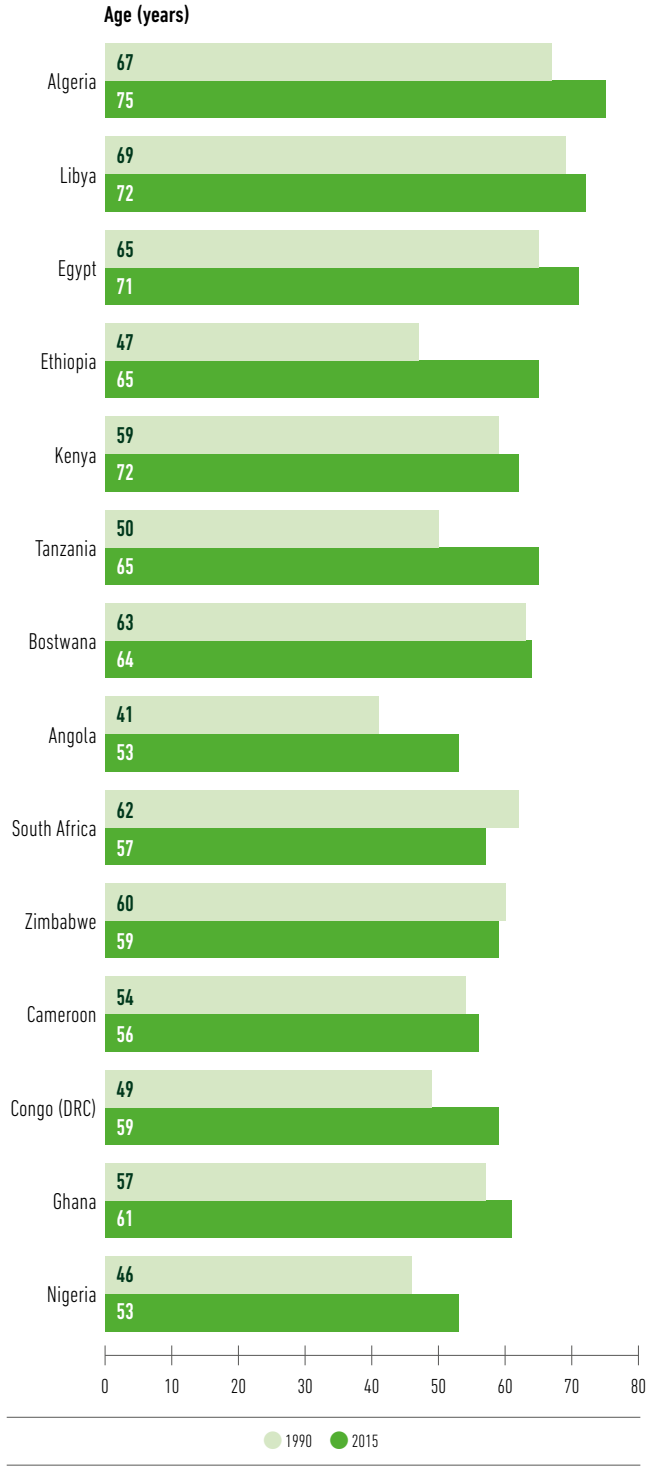

Figure 2.3. Life expectancy at birth in Africa.
Source: World Bank, 2017.

SDG 4: Quality education – The secondary school completion rate in sub-Saharan Africa has increased from 23% in 1990 to 42% in 2014, but is still very low compared to the world average of 75% (World Bank, 2017). Of the world's 58 million primary school-age children who were out of school in 2015, more than half of them were girls and nearly 75% of them were from sub-Saharan Africa and southern Asia (UNDESA, 2015). Despite a significant increase in enrolment rates at primary and secondary level, there is a need to invest more in the higher education infrastructure and to reform education curricula to curb the deteriorating quality of education and promote transdisciplinarity. The number of college and university graduates in the region is growing; however, the poor quality of education means that most new graduates lack the practical skills needed in the job market and growing industries (UNECA, 2015*a*).

SDG 5: Gender equality – African women still face challenges such as exposure to harmful cultural practices (e.g. early marriages), a lack of equitable economic/learning opportunities and barriers to participation in politics (UNECA, 2015*b*).The early marriage of girls is still common in sub-Saharan Africa, where the age gap between spouses is the widest in the world (men are on average 4.8 years older than their wives) (UNDESA, 2015). Thus, young women who are married to older men are more likely to face domestic violence and to lack decision-making status in a family. The report points out that women who are married early are more likely to lose access to information and education. Moreover, the age gap itself increases the chance of misunderstandings and the economic dependency of women on their husbands, which can lead to men imposing their decisions, often abusively. However, there has been a significant improvement in the enrolment of girls in schools. For example, girls' enrolment in secondary schools has increased from 71 girls for every 100 boys in the 1990s to 90 girls for every 100 boys in 2013 (UNECA, 2015*c*). Women researchers account for 30.4% of sub-Saharan African researchers and the number of women joining natural science fields is increasing. This share is higher than in some regions, such as South and West Asia (19.0%), East Asia and the Pacific (22.9%), and the world average (28.8%) (UNESCO UIS, 2017).

SDG 6: Clean water and sanitation – Currently, over 91% of the world population has access to clean and safe water (Population Reference Bureau, 2016). However, only 24% of sub-Saharan Africa's population had access to safe drinking water and only 28% had access to basic sanitation services in the year 2015 (WHO and UNICEF, 2017). According to the same report, of the 159 million people who depend on surface water sources for drinking in the world, 58% live in sub-Saharan Africa. Most African countries have limited financial and technical capacities to optimize the use and management of their water resources; hence, they will continue to face critical challenges that include water scarcity (e.g. due to drought), water pollution, and poor infrastructure for abstracting, treating, storing and distributing water to their citizens (Jiménez et al., 2017; Mugagga and Nabaasa, 2016).However, some countries have come up with innovative solutions. For example, a company in Kenya has introduced water ATMs that use AQtap technology to improve access to clean water at an affordable cost (UNDESA, 2018).

SDG 8: Decent work – The unemployment rate is still high in northern and southern Africa (**Figure 2.4**). Only about 17% of the African youth population aged 15–35 have stable jobs (AfDB, 2016).[10] At the country level, Ghana, Cape Verde and Mali have high unemployment rates, while Benin, Burkina Faso and Niger have maintained low unemployment rates (UNECA, 2015*a*).

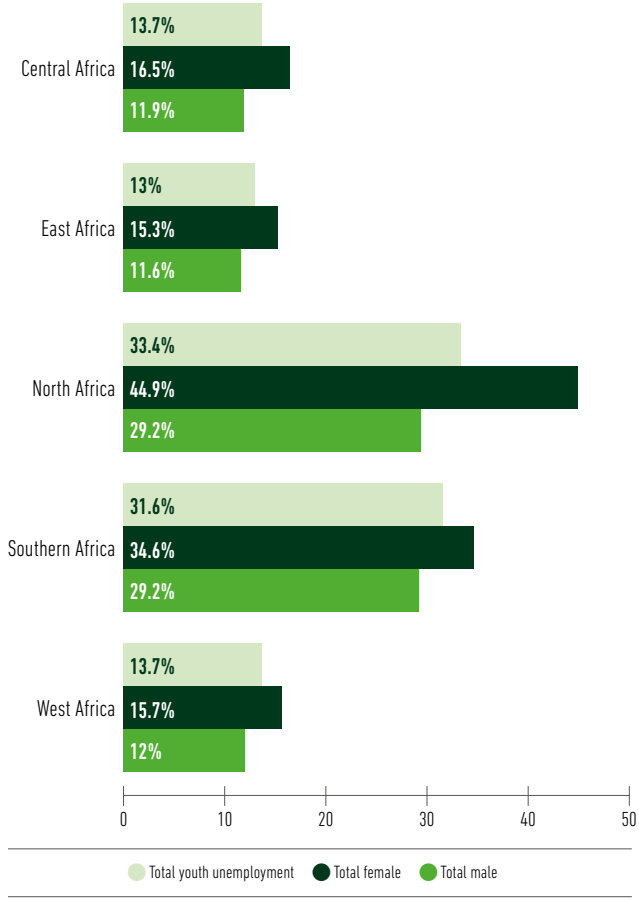

Figure 2.4. Youth unemployment rate in Africa.
Source: ILO, 2014.

10 African Development Bank Jobs for Youth in Africa Strategy 2016–2025 Initiative. www.afdb.org/en/topics-and-sectors/initiatives-partnerships/jobs-for-youth-in-africa

SDG 10: Reduced inequalities – Sub-Saharan Africa has registered strong economic growth over the past two decades. This was mainly due to increased trade between Africa and other parts of the world, which quadrupled between 1995 (US$197 billion) and 2015 (US$852 billion) (AfDB et al., 2017). According to the same source, other factors for economic growth include an upsurge of foreign direct investment (FDI) following the 2007–2008 global financial crisis, improved macroeconomic management, political stability and the presence of a cheap labour force. However, these economic gains did not significantly reduce prevalent income inequalities (Dalia et al., 2016). South Africa and Namibia have the highest inequality rates in the continent with the same Gini coefficient of 0.63, while Ethiopia has the lowest inequality rate with a Gini coefficient of less than 0.30 (JICA, 2013). In terms of income inequality, Africa ranks second in the world (next to Latin America and the Caribbean region) and its gender inequality remains one of the highest in the world (UNESCO and EOLSS, 2012).

SDG 11: Sustainable cities and communities – The urban population in sub-Saharan Africa is growing by 4% annually and will double itself within two decades (World Bank, 2017). The rate is much higher than the 2% world average, which is not surprising given the rapid population growth and deterioration of conventional means of livelihoods in rural areas. However, half the urban dwellers in the region live in slums and face enormous challenges to meet their basic needs (World Bank, 2017). These include lack of skills and experience to strategically plan and administer complex megacities and metropolises, rampant corruption and flawed land policies (Centennial, 2013; Fox, 2014).

SDG 7: Affordable and clean energy – Access to clean and affordable energy is poor and irregular in Africa. For example, only 25% of the sub-Saharan African population has access to electricity, while this rises to 80% in other regions like North Africa, albeit from non-renewable energy sources like coal and petroleum (UNECA, 2015*a*). Due to its high dependence on traditional biomass fuels, sub-Saharan Africa has the highest share, with over 70% of renewable in its energy use (World Bank, 2017). According to the same source, the number of people without access to electricity in the region has increased from 58 million in 1991 to over 108 million in 2014. The African population is projected to reach 1.5 billion by 2030 under the 'business-as-usual' scenario (UNECA, 2015*a*). Nonetheless, 44% of this population will not have access to electricity, while 59% will depend on non-clean cooking facilities such as biomass fuels which remain the dominant cooking fuels in the continent (UNECA, 2015*a*).

SDG 16: Peace, justice and strong institutions – Widespread political repressions, unconstitutional power abuse (leaders clinging to power), fake and fraud elections, etc. have become recipes for ongoing protests and conflicts in the continent. Governance challenges include weak institutions, poor public service (unskilled civil servants) and rampant corruption. For example, Africa loses about US$300 billion in corruption annually (Ojo et al., 2016). Fixing most of these needs real political commitment with competent leadership.

Economic challenges

SDG 8: Economic growth – Economic growth rates in Africa have been impressive, averaging 4% in 2013 (UNECA, 2015*c*). However, the share of natural capital in economic growth is still high (19%) in Africa – the second largest in the world next to Oceania (UNU-IHDP and UNEP, 2014). Within its regions, middle and eastern Africa are the most dependent on natural capital for their economic growth, with shares of 40% and 20% respectively. According to the same source, the contribution of produced goods to economic growth in Africa was only 20% in 2014, which is the lowest in the world. Like the world economy, Africa has targeted an average of 7% economic growth during the SDG implementation period (Ighobor, 2015). For example, Ethiopia has achieved 8% economic growth in the 2016/2017 fiscal year, which is more than three times sub-Saharan Africa's average of 2.5%. However, the growth was lower than its plan of 11% due to drought and political unrest in the country (National Planning Commission of Ethiopia, 2017). Similarly, Kenya's tourism sector has been negatively affected by the rise of transnational terrorism and crime, and its contribution to the economy is declining. As a countermeasure, the country has established a youth enterprise fund to empower young entrepreneurs to start their own businesses and boost economic growth (UNDESA, 2018). The falling price of commodities (e.g. oil) has also slowed economic growth in countries like Nigeria and Angola (AUC, 2015).

SDG 9: Industry, innovation and infrastructure – Manufacturing of value added (MVA) products and its share of a country's GDP is one of the indicators for industrialization. According to the World Bank (2017) data, the regional share of MVA to GDP is 11% in sub-Saharan Africa and is the lowest in the world, compared to 16% in Europe and Asia and 14% in Latin America and the Caribbean. The region has competitive advantages, such as cheap labour, to attract and expand light manufacturing (e.g. textiles). However, most of the potential youth workforce in the continent lack the required skills (El-hadj and Chouchane, 2017) and an enabling environment to promote sustainable innovation and industrialization.

SDG 17: Partnerships for the goals – Most African countries lack the necessary human capacity, policies and access to technology to implement the SDGs. Hence, they need strong partnerships with the global communities to acquire the necessary support (technical, financial and technological). For instance, Google is training 125,000 young Nigerians through its programme 'Digital Skills for Africa' to enhance their technical and business skills (UNDESA, 2018). Moreover, African countries rely heavily on external funds to conserve and sustainably use their terrestrial and marine resources (Dugarova and Gülasan, 2017).

Environmental challenges

SDG 12: Ensure sustainable consumption and production patterns – The growing middle class of Africa is becoming affluent and changing its consumption patterns, despite the declining resource base and low production of materials (AfDB et al., 2017). According to the same source, FDI in Africa increased by 22% between 2010–2014 and this has contributed to the growth of the middle class through the creation of employment opportunities. As a result, employees had increased purchasing power for consumables and modern electronic devices, such as smartphones and TVs. However, most of those foreign investments were on extractable commodities, and a slowdown has occurred after 2015, due to depletion of these resources and price reductions. Since 2016, the FDI in Africa has focused more on infrastructure developments, manufacturing and service sectors (AfDB et al., 2017). The challenge, in this case, is to fulfil the needs of these growing populations while effectively conserving the resource base and safely managing the waste generated by consumption. For instance, proper handling and disposal of electronic and chemical waste requires special skills and facilities that are inadequate or totally absent in most African countries.

SDG 13: Climate change – Climate change is the number one challenge to the realization of various SDGs related to agriculture, health and water, especially in Africa. For example, agriculture is the backbone of the economy in many African countries. Besides food production, it is the main source of employment and raw materials for primary industries. However, it is predominantly rain-fed, low-production subsistence farming and is therefore extremely vulnerable to climate change. Ongoing efforts to modernize and move to climate-smart agriculture are being constrained by a lack of adequate human, financial and technical capacities in some countries (Begashaw and Shah, 2017). Accordingly, countries are taking various adaptive and mitigation measures. For example, Nigeria has trained over 500 agricultural extension workers to communicate climate information to rural farmers to help the public understand and adapt to climate change, while Kenya is working to integrate climate change into the curricula of primary and secondary education (UNDESA, 2018).

SDG 14: Life on land – Land degradation, pollution, over-exploitation of resources, desertification and deforestation, among other practices, are increasing biodiversity loss across the continent. For instance, about two-thirds of sub-Saharan Africa's agricultural lands have already been seriously degraded due to poor land management practices, uncontrolled agricultural expansion and climate change (e.g. floods) (UNESCO and EOLSS, 2012). Some attempts to rehabilitate such lands have been faced with critical financial shortages and technical limitations. For example, Ethiopia has undertaken extensive tree planting along the main watersheds to rehabilitate degraded agricultural lands and protect its hydropower dams, with public participation (National Planning Commission of Ethiopia, 2017). As a result, some remarkable changes have been achieved, including an increment in forest-coverage, reduction in sediment transportation and replenishment of groundwater.

2.3.2. Trends and patterns of sustainable development and sustainability research in Africa

Results from the literary survey revealed that there has been a steady increase of SDG-related literature in the last 10 years focusing on Africa (see **Figure 2.5**). The Scopus search shows an average annual growth rate of the literature landscape by 6% between 2008 and 2016, having a higher production of literature in the last five years compared to the previous five years. The total number of documents produced between 2013 and July 2017 is 26% higher compared to documents produced between 2008–2012. With the exception of an expected increase of press articles for recent years, due to journal production cycles, the overall share of document types within a year remains similar. Original research articles represent the highest literature output, averaging above 70% of the total literature produced in the last 10 years (see **Appendix 2.2**).

The focus of the SDGs, on the other hand, shows some interesting changes. **Figure 2.6** indicates three distinct clusters of SDG literature collections, grouped by level of annual literature production:

1. **Cluster 1:** low SDG literature output with production below 150 documents annually;
2. **Cluster 2:** medium SDG literature output with production between 150–350 documents annually;
3. **Cluster 3:** high SDG literature output with over 350 available documents.

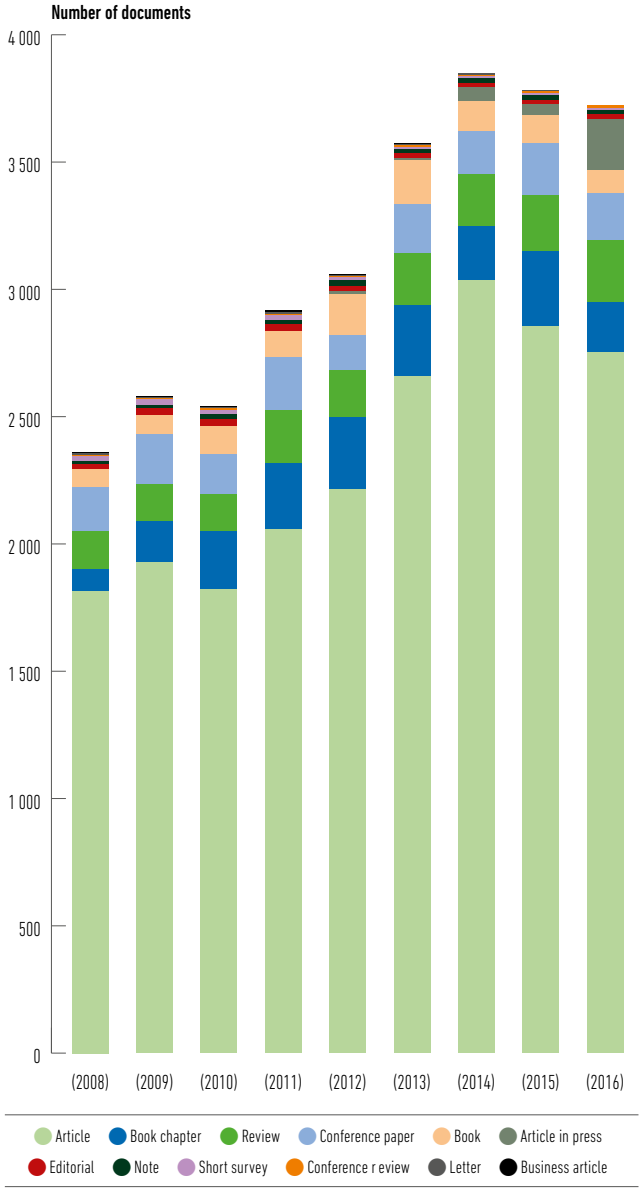

Figure 2.5. SDG-related publication trend, including all document types.

Source: Scopus.

While the SDGs within each cluster have remained the same over the last 10 years, there are some changes between and within the clusters. SDGs related to poverty, gender equality and climate action integrate cluster 3. These three SDGs account for 50% of the entire literature landscape over the last 10 years and while the cluster contribution remains roughly the same, there is a clear change within it. In contrast to literature related to gender equality and climate action, which exhibits a steady growth pattern, poverty studies have seen a sharp decline since 2014. Moreover, cluster 2, populated by SDGs related to health,

Photo 2.1. Women form the majority of the labour force for food production in Africa.
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economic growth and inequalities, among other areas, has seen a faster average annual growth rate at 8% in the last 10 years compared to the other 2 clusters (**Appendix 2.3**), growing faster than the 6% of the literature landscape.

Cluster 1 groups about half of the SDGs, yet their combined output represents only 11% of total documents produced in the last 10 years. Furthermore, the cluster is growing more slowly than the entire literature landscape, with an annual average growth rate of 5.9%. Despite the high production of documents related to poverty (SDG 1), most of its interlinked goals, including clean water and sanitation (SDG 6), industry innovation (SDG 9), sustainable cities (SDG 11), and strong institutions (SDG 16) (ICSU, 2017; Zhou and Moinuddin, 2017) are within this low-production cluster. Similarly, documents related to goals interlinked with climate action (SDG 13) from cluster 3, including life below water (SDG 14), clean and affordable energy (SDG 7), and responsible production and consumption (SDG 12), are lagging behind.

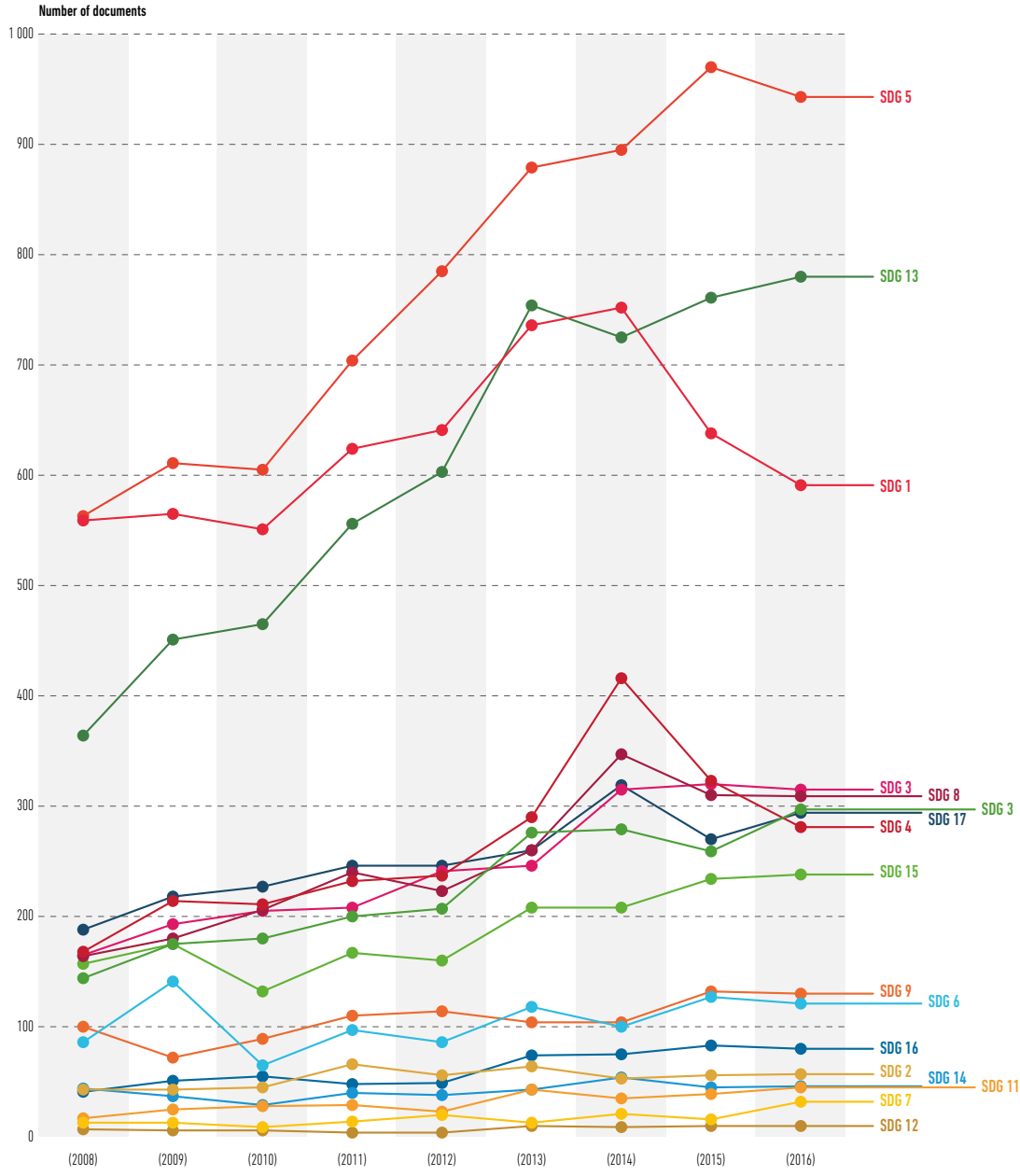

Figure 2.6. SDG literature collection cluster trends including all document types by year.
Source: Scopus.

There has also been an increase in scope during the last 10 years. Literature that addresses more than one SDG is growing. Although these studies currently represent less than 20% of the total published literature (**Figure 2.7**), they show a positive trend, growing faster compared to the 6% of the literature landscape. **Figure 2.8** shows the publication trends of literature, linking up to 6 SDGs with an average annual growth rate of 7%.

The word cloud created for each literature collection helps to clarify the key areas of study for each SDG over the past 10 years (**Appendix 2.4**) and provides an overall image showing where funding has been allocated (Benavente et al., 2012; Bloch et al., 2014; Fedderke and Goldschmidt, 2015). The highest trending themes provide sufficient information to identify the what, who, where and why of each SDG. This result allows for interpretation at a broad level on the types of discussion that have taken place within the research community (e.g. adaptation, mitigation) and on the most pressing concerns explored (i.e. food security, water resources, rainfall). It also helps to identify the main stakeholders involved in these issues (i.e. children, women, government); where attention been focused (i.e. community, associations, forest, oceans); and the causes and types of pressures (i.e. population, droughts, policies).

Figure 2.9 illustrates the word cloud for the SDGs contained in cluster 3, representing more than 50% of Africa's sustainable development literature landscape. The results reveal that each SDG has a distinctive tendency toward one of the sustainability dimensions.

- **SDG 1** explores Africa's poverty challenges and its highest-ranking themes show an inclination towards the economic dimension (Figure 2.9a.). Its discussion evolves around the economy, including poverty, income and food security ('what'). It highlights households, women, children and government as frequent stakeholders ('who') in both urban and rural areas ('where'); and shows policies, urbanization and livelihood as key factors in the discussion ('why').
- **SDG 5** examines the gender equality challenges in the continent and the results show a discussion skewed towards the social dimension (Figure 2.9b.). The key point of interest is around gender issues, rights and inclusiveness ('what') for women and children, and other actors such as educators ('who'). SDG 5 is centred at various levels of society including communities, associations and various groups ('where') and identifies pressures such as culture and HIV ('why').
- **SDG 13** addresses Africa's climate action, exhibiting a tendency towards the environmental dimension (Figure 2.9c.). The studies are concentrated on topics related to agriculture, water resources, adaptation and globalization ('what'). SDG 13 is centred mainly on the environment and species biodiversity ('who') in the forest and other land areas ('where'); identifying climate change and economic development as the main pressure factors ('why').

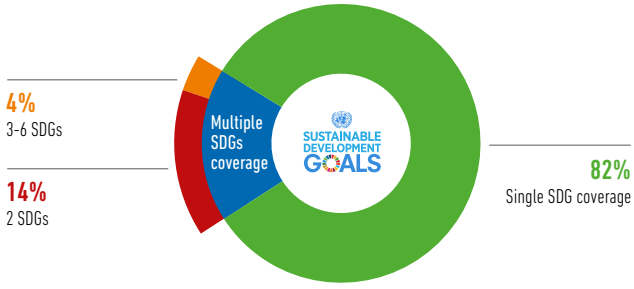

Figure 2.7. Proportion of documents covering more than one SDG.
Source: Scopus.

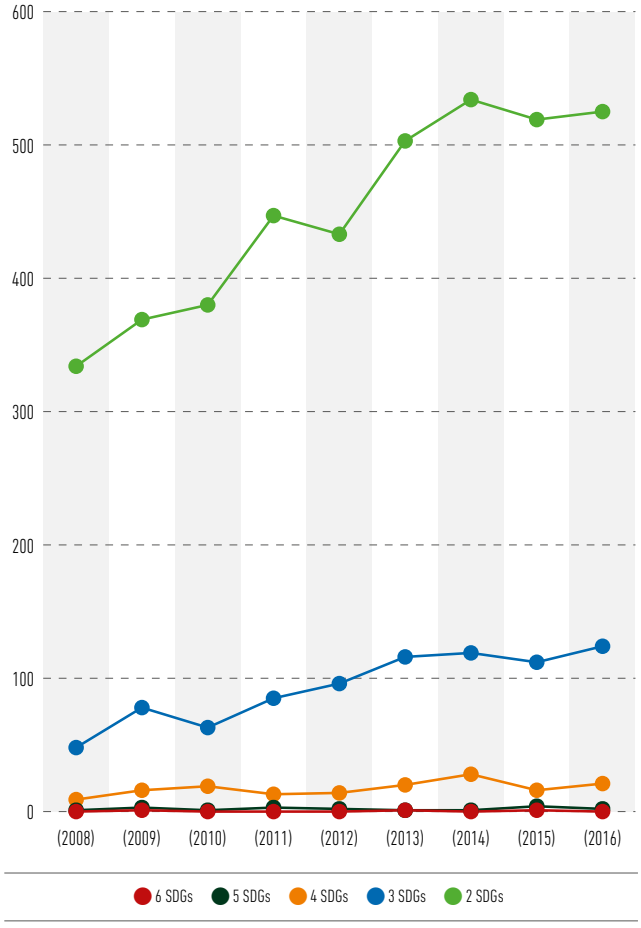

Figure 2.8. Yearly trend of publications covering more than one SDG.
Source: Scopus.

Figure 2.9. Word cloud for SDGs belonging to cluster 3 of the literature landscape review (a= SDG 1; b=SDG 5; c = SDG 13).
Source: Scopus 'literature collection'.

2.4. Comparison matrix of three different literature sources

Figure 2.10 shows a cross-check of the most relevant themes by SDG for each literature source. The emergence of the same relevant themes across literature sources signal a higher consensus of which are Africa's development priorities, resulting in a smaller list of themes (see SDGs 6 and 13 in **Figure 2.10**), while there is less agreement regarding issues on a longer list of priorities to be addressed (see SDGs 10, 11 and 14 in **Figure 2.10**). A higher consensus on SDG 6 and SDG 13 was found, showing a closer alignment between the knowledge produced in the academic research community and what have been identified as policy-relevant issues by the international community. Regarding clean water and sanitation (SDG 6), the results show that improving access is a key priority, whereas for climate action (SDG 13), climate and rainfall changes are the most pressing concerns.

On the other hand, we also found a larger spread of priorities in SDGs 10, 11 and 14. Reduced inequalities (SDG 10) lean towards economic concerns, including inequalities and inequities in development, income and employment. Sustainable cities and communities (SDG 11) lean towards social concerns, including development, safety and livelihood in slums, rural and urban areas, and its effects on the population. Life below water (SDG 14) leans towards environmental concerns, including fish stocks and biodiversity loss in oceans and island systems.

This matrix helps to identify themes that are not mentioned in a literature source but are a top priority for the remaining sources. This mismatch of priorities among sources has a higher presence in SDGs 3, 9 and 10. The World Bank Atlas does not mention a population with good health and well-being (SDG 3) as Africa's development priority. Some themes that have been identified as relevant in the academic community have been overlooked by the policy-relevant documents, the theme of 'innovation' is missing from both the World Bank and AUC in addressing SDG 9, as well as 'inequities' as a relevant factor for addressing SDG 10.

2.5. Interlinkages between SDGs

Figure 2.11 identifies the strongest connection between goals as well as the weakest links after combining all three literature sources into a single view. It also highlights which SDG has the largest theme coverage across all 17 goals. The results do not show any predominant set of interlinkages (represented by the wider line) between goals but help to identify the group of SDGs with the largest theme coverage that include goals related to poverty (SDG 1), gender equality (SDG 5), climate action (SDG 13) and life on land (SDG 15). The results also show the weakest theme coverage, which includes goals related to clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), and industry, innovation and infrastructure (SDG 9).

It is worth noting that these results are not similar across literature sources. On the one hand, Scopus clearly identifies few predominant links and theme coverage, namely between poverty (SDG 1), gender equality (SDG 5) and climate action (SDG 13). On the other hand, literature sources from the AUC and the World Bank show similar results to the combined view, where no largely predominant set of linkages is found.

Figure 2.10. Top three ranking themes by literature source.

Source: Scopus 'literature collection'.

Green grids represent the theme ranked below the top three for the specified literature source, blue grids denote that the theme belongs to the top three for the specified literature source, and light orange grids show that the theme has not been mentioned within the specified literature source.

The figures show that AUC identifies life on land (SDG 15) as the most connected and relevant goal, while reduced inequalities (SDG 10) and sustainable cities and communities (SDG 11) appear as the least-connected, with the lowest theme coverage (**Appendix 6**). The World Bank identifies life below water (SDG 14), life on land (SDG 15) and partnerships for the goals (SDG 17) as the strongest in terms of connection and theme coverage, while quality of education (SDG 4) and clean water and sanitation (SDG 6) are revealed to have the weakest connection and coverage (**Appendix 2.7**).

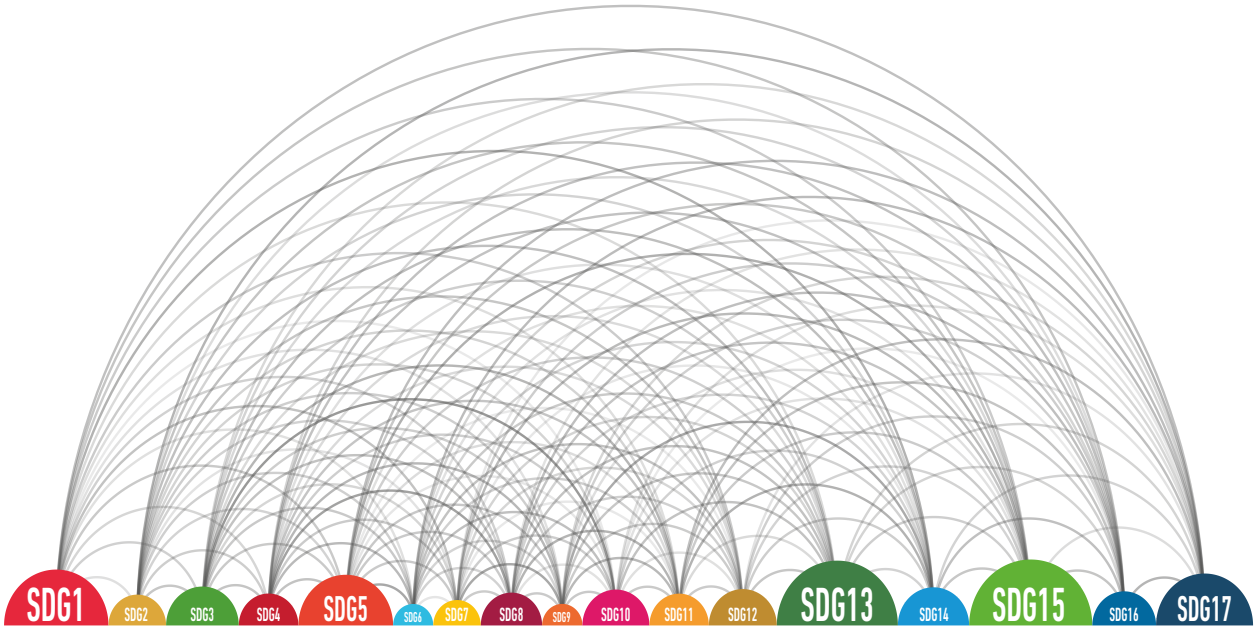

Figure 2.11. SDG linkages and coverage across all literature sources.
Source: Scopus 'literature collection'.

2.6. Identifying overarching themes

While identifying the strongest links between SDGs leads to a closer understanding of the synergies in the region, it lacks the level of detail needed to identify the mechanism through which this can be done (ICSU, 2017). Therefore, in order to identify which theme can become a mechanism to promote synergies between SDGs, the links between themes and SDGs are explored for each literature source (**Figure 2.12**). The outcome shows mixed results: development and economy play a key role as overarching mechanisms across the SDGs based on Scopus and the AUC, while addressing poverty is the main mechanism identified by the World Bank Atlas and the AUC.

The results show a level of disconnection between the scientific literature produced by the African research community and the priorities identified by the AUC and the World Bank Atlas. According to these, 'reducing poverty' and 'people' [community] emerge as key mechanisms that interlink SDGs and define a path to address the continent's development priorities, whereas the literature landscape analysis from Scopus shows a research focus on themes such as 'economy' and 'climate change'.

Moreover, the AUC has identified 'urbanization' as a key mechanism to harness synergies between SDGs (**Figure 2.12**), yet studies related to sustainable cities and communities (SDG 11) are still scarce (**Figure 2.6**). 'Development' is logically shown as a grounding mechanism that interlinks SDGs from all three clusters, yet there is an imbalance in SDG literature production between goals from cluster 1 and cluster 3. The research community will increase its efforts to reduce these production gaps through mechanisms able to link multiple SDGs (i.e. SDG 11 to address sustainable urbanization), and interlinked SDGs from cluster 1. If Africa is to achieve its SDGs by 2030, researchers and funding allocation need to be distributed so as to concentrate efforts on the priorities which have been identified as critical.

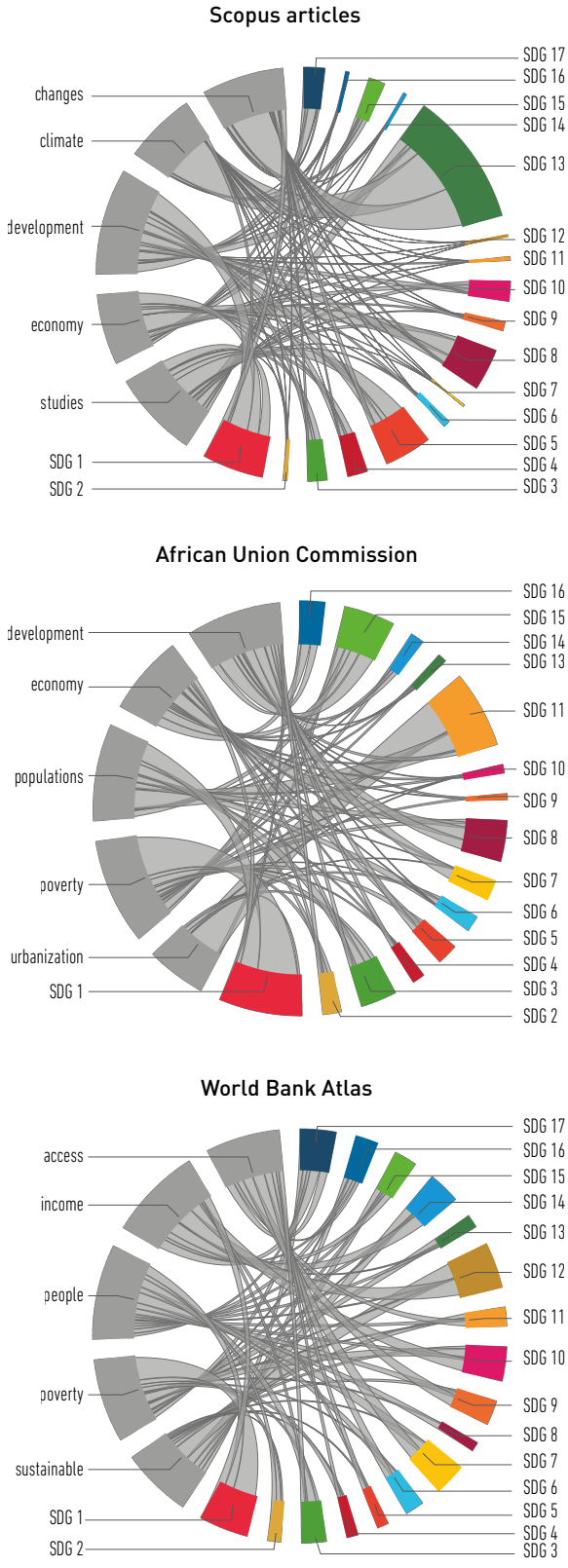

Figure 2.12. Theme and SDG linkages for each literature source.
Source: Scopus 'literature collection'. Note: Bottom green corresponds to SDG 3 in Scopus and World Bank Atlas

2.7. Conclusions

This chapter aimed to use the 17 SDGs to analyse current trends, patterns, directions and linkages of scientific research, academic studies and publications on sustainable development and sustainability issues in Africa, and to assess the synergies between sustainability research themes and sustainable development priorities (practical implementation strategies). As briefly highlighted in section 2.3.1, the statistics indicate that Africa has shown some progress in some SDGs (e.g. 3, 4 and 5) but it is still lagging behind in most of them. Uneven performances at regional and national level are due to challenges including low political commitment, high dependency on foreign funds, lack of reliable data, and shortage of human and financial capital, among others (**Table 2.1**).

Addressing these challenges requires a strong sustainability approach – this is missing from the findings of our present study. The steady increase of literature addressing SDGs in the continent is evidence that the research community, policy- and decision-makers and other relevant stakeholders interested in addressing Africa's sustainable development challenges are there. The present growth from the bibliometric review hints at a slow trend towards a more diverse set of studies and research beyond poverty, gender equality and climate actions. Furthermore, the surge of studies embracing more than one SDG gives us an idea of the increased spread of transdisciplinary analyses. Despite this encouraging news, there is a thematic mismatch of priorities between literature sources and a skewed focus towards one or another sustainability pillar, which indicates that more needs to be done. Research studies and research funding allocation should address the continent's priorities and its specific and complex challenges. Educational curricula across Africa need to be reformed and realigned with sustainability science principles, concepts and themes at all levels of the educational system.

While published literature in Scopus covers most of Africa's development priorities identified by the AUC and the World Bank Atlas, there are serious gaps and mismatches between academic works (Scopus) and development needs stated by AUC and the World Bank Atlas (**Figure 2.10**). For example, we observe that achieving peace, justice and strong institutions (SDG 16) are among the top priorities in the region, based on the literature reviewed and the SDG linkages analysis (**Appendix 2.6**). However, limited research has been conducted on these topics.

While the increase in the body of theoretical and empirical data and knowledge on sustainability-related issues in Africa is laudable, the low level of synergy and connectivity between issues presents a major challenge as far as applying research outputs is concerned. In this sense, there is an urgent need for the integration of the viewpoints and needs of relevant stakeholders in the scientific and non-scientific community. It is therefore important that African researchers and scientists are entitled to drive the agenda towards more transdisciplinary, collaborative and participatory science research. A strong sustainability approach with African researchers, academics and policy-makers at the forefront will ensure that research outputs will be more relevant and useful to practitioners, communities, and suitable to the development needs and priorities of the continent.

Photo 2.2. Funding for applied research that responds to societal needs is key to achieving SDGs in the region
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References

Adriaanse, L. S. and Rensleigh, C. 2013. Web of Science, Scopus and Google Scholar. *The Electronic Library*, Vol. 31, No. 6, pp. 727–44. https://doi.org/10.1108/EL-12-2011-0174.

AfDB, OECD and UNDP. 2016. *Africa Economic Outlook 2016: Regional Development and Spatial Inclusion*. Paris, OECD

AfDB, OECD and UNDP. 2017*a*. *Africa Economic Outlook 2016: Sustainable Cities and Structural Transformation*. Paris, OECD

AfDB, OECD and UNDP. 2017*b*. *African Economic Outlook 2017*. African Development Bank (AfDB), Organisation for Economic Co-operation and Development (OECD)and United Nations Development Programme (UNDP).

AU. 2017. *African Sustainable Development Report: Tracking Progress in Agenda 2063 and Sustainable Development Goals*. African Union, Economic Commission for Africa, African Development Bank, United Nations Development Programme, Addis Ababa.

AUC. 2015. *African Union Commission Agenda 2063: The Africa We Want. First Ten-Year Implementation Plan*. Addis Ababa, African Union.

Ayodele O., Cornia, G. A., Bhorat H. and Conceição, P. 2017. *Income Inequality Trends in sub-Saharan Africa*. UNDP. Retrieved from: http://www.africa.undp.org/content/dam/rba/docs/Reports/Overview-Income inequality Trends SSA-EN-web.pdf%0Aafrica.undp.org

Beegle, K., Christiaensen, L., Dabalen, A. and Gaddis, I. 2016. *Poverty in a Rising Africa*. The World Bank. https://doi.org/10.1596/978-1-4648-0723-7

Begashaw, B. and Shah, A. 2017. SDG financing for Africa: Key propositions and areas of engagement. Discussion paper for development finance workshop. Kigali, SDG Center for Africa.

Benavente, J. M., Crespi, G., Figal Garone, L. and Maffioli, A. 2012. The impact of national research funds: A regression discontinuity approach to the Chilean FONDECYT. *Research Policy*, Vol. 41, No. 8, pp. 1461–75. https://doi.org/10.1016/j.respol.2012.04.007

Bengtsson, M. 2016. How to plan and perform a qualitative study using content analysis. *NursingPlus Open*, Vol. 2, pp. 8–14. https://doi.org/10.1016/j.npls.2016.01.001

Bettencourta, L. and Kaurc, J. 2011. Evolution and structure of sustainability science. *PNAS*, Vol. 108, No. 49, pp. 19540–45.

Bloch, C., Sørensen, M. P., Graversen, E. K., Schneider, J. W., Schmidt, E. K., Aagaard, K. and Mejlgaard, N. 2014. Developing a methodology to assess the impact of research grant funding: A mixed methods approach. *Evaluation and Program Planning*, Vol. 43, pp. 105–17. https://doi.org/10.1016/j.evalprogplan.2013.12.005

Burns, M. and Weaver, A. (eds). 2008. *Exploring Sustainability Science: A Southern African Perspective*. Stellenbosch, African SUN MeDIA.

Centennial. 2013. *Development Challenges in Africa Towards 2050*. Tokyo, JICA Research Institute.

Dalia, H.S., Mumtaz, H., Newiak, M., Thakoor, V. and Yang, F. 2016. Inequality, Gender Gaps and Economic Growth: Comparative Evidence for Sub-Saharan Africa. World Bank, Working Paper No. 16/111.

Dedeurwaerdere, T. 2013. Sustainability science for strong sustainability. *Sustainability Science for Strong Sustainability*, January, pp. 1–115. https://doi.org/10.4337/9781783474561

Dugarova, E. and Gülasan, N. 2017. *Global Trends: Challenges and Opportunities in the Implementation of the Sustainable Development Goals*. New York, UNRISD.

ECA. 2013. *Sustainable Development Challenges. World Economic and Social Survey*. New York, United Nations. Retrieved from: https://sustainabledevelopment.un.org/content/documents/2843WESS2013.pdf

El-hadj and Chouchane. 2017. Competitive African cities for better living standards. *The Africa Competitiveness Report 2017*. Geneva, World Economic Forum.

FAO. 2017. *The future of Food and Agriculture: Trends and Challenges*. Retrieved from http://www.fao.org/publications/card/en/c/d24d2507-41d9-4ec2-a3f8-88a489bfe1ad/

Fedderke, J. W. and Goldschmidt, M. 2015. Does massive funding support of researchers work?: Evaluating the impact of the South African research chair funding initiative. *Research Policy*, Vol. 44, No. 2, pp. 467–82. https://doi.org/10.1016/j.respol.2014.09.009

Fox, S. 2014. The political economy of slums: Theory and evidence from sub-Saharan Africa. *World Development*, Vol. 54, pp. 191–203. https://doi.org/10.1016/j.worlddev.2013.08.005

Gasparatos, A., Takeuchi, K., Elmqvist, T., Fukushi, K., Nagao, M., Swanepoel, F., Swilling, M., Trotter, D. and von Blottnitz, H. 2017. Sustainability science for meeting Africa 's challenges: Setting the stage. *Sustainability Science,* Vol. 12, pp. 635–40.

Hakura, D., Hussain, M., Newiak, M.,Thakoor, V. and Yang, F. 2016. *Inequality, Gender Gaps and Economic Growth: Comparative Evidence for Sub-Saharan Africa* (IMF Working Paper No. 16/111). Washington, DC, IMF.

Handley, G., Higgins, K., Sharma, B. and Cammack, D. 2009. *Poverty and Poverty Reduction in Sub-Saharan Africa: An Overview of the Issues*. (ODI Working Paper, 82.)

Harzing, A.-W. and Alakangas, S. 2016. Google Scholar, Scopus and the Web of Science: A longitudinal and cross-disciplinary comparison. *Scientometrics*, Vol. 106, No.2, pp. 787–804. https://doi.org/10.1007/s11192-015-1798-9

ICSU. 2017. *A Guide to SDG Interactions: From Science to Implementation*. Paris, International Council for Science (ICSU). https://doi.org/10.24948/2017.01

IEA (International Energy Agency). 2014. *Africa Energy Outlook: A Focus on Energy Prospects in Sub-Saharan Africa.* Paris, OECD.

IFPRI. 2017. *2017 Global Hunger Index: The Inequalities of Hunger.* Washington DC, International Food Policy Research Institute. www.ifpri.or/topic/global-hunger-index

Ighobor, K. 2015. *Sustainable Development Goals in Sync with Africa's Priorities*. New York, UN.

ILO. 2014. *Executive Summary of the World of Work Report 2014: Developing with Jobs.* Geneva, ILO.

International Energy Agency. 2014. *Africa Energy Outlook. A Focus on Energy Prospects in Sub-Saharan Africa*. Paris, IEA.

IPCC. 2014. *Climate Change 2014, Mitigation of Climate Change, Summary for Policy Makers and Technical Summary*. Fifth Assessment Report of the Intergovernmental Panel on Climate Change, WMO-UNEP.

Jaeger, C. C. and Tàbara, J. D. 2011. C. C. Jaeger, J. D. Tàbara and J. Jaeger (eds), *European Research on Sustainable Development*, Vol. 1, pp. 205–08.

Jaeger, W. K., Amos, A., Bigelow, D. P. Chang, H., Conklin, D. R., Haggerty, R., Langpap, C., Moore, K., Mote, P. W., Nolin, A. W., Plantinga, A. J., Schwartz, C. L., Tullos, D. and Turner, D. P. 2017. Finding water scarcity amid abundance using human–natural system models. *Proceedings of the National Academy of Sciences*, Vol. 114, No. 45, pp. 11884–89. Published ahead of print October 23, 2017. https://doi.org/10.1073/pnas.1706847114

Jaiyesimi, R. 2016. The challenge of implementing the Sustainable Development Goals in Africa: The way forward. *African Journal of Reproductive Health*, Vol. 20, No. 3, pp. 13–18.

JICA. 2013. *Development Challenges in Africa Towards 2050*. Tokyo, JICA.

Jiménez, A., Jawara, D., LeDeunff, H., Naylor, K. and Scharp, C. 2017. Sustainability in practice: Experiences from rural water and sanitation services in West Africa. *Sustainability*, Vol. 9, No. 3, p. 403. https://doi.org/10.3390/su9030403

Kajikawa, Y. 2008. Research core and framework of sustainability science. *Sustainability Science*, Vol. 3, No. 2, pp. 215–39.

Kajikawa, Y., Ohno, J., Takeda, Y., Matsushima, K. and Komiyama, H. 2007. Creating an academic landscape of sustainability science: an analysis of the citation network. *Sustainability Science*, Vol. 2, No. 2, pp. 221–31

Kajikawa, Y., Tacoa, F. and Yamaguchi, K. 2014. Sustainability science: the changing landscape of sustainability research, October 2014, *Sustainability Science*, Vol. 9, No. 4, pp. 431–38.

Kakonge, J. O. 2012. *Challenges of Achieving Millennium Development Goals in Africa by 2015: Some Reflections*. Wiley Online Library. https://doi.org/10.1111/j.1758-5899.2011.00166.x

Kakonge, J. O. 2012. Improving development project implementation through effective communications. *Global Policy*. Retrieved from http://www.globalpolicy.

Kates, R. W. 2011. What kind of a science is sustainability science? *PNAS*, Vol. 108, pp. 19449–50.

Kates, R. W. and Dasgupta, P. 2007. African poverty: a grand challenge for sustainability science. *PNAS*, Vol. 104, pp. 16747–50.

Komiyama, H. and Takeuchi, K. 2006. Sustainability science: Building a new discipline. *Sustainability Science*, Vol. 1, pp. 1–6.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M. and Thomas C. J. 2012. Transdisciplinary research in sustainability science: Practice, principles and challenges. *Sustainability Science,* Vol. 7, No. 1, pp 25–43.

Laurance, W. F. et al. 2012. Averting biodiversity collapse in tropical forest protected areas. *Nature*, Vol. 489, pp. 290–94.

Maathai, W. 2011. Challenge for Africa. *Sustainability Science*, Vol. 6, No. 1, pp. 1–2.

Molini, V. and Paci, P. 2015. *Poverty Reduction in Ghana: Progress and Challenges*. Washington DC, World Bank. https://doi.org/10.1596/K8485

Mongeon, P. and Paul-Hus, A. 2016. The journal coverage of Web of Science and Scopus: A comparative analysis. *Scientometrics*, Vol. 106, No. 1, pp. 213–28. https://doi.org/10.1007/s11192-015-1765-5

Mugagga, F. and Nabaasa, B. B. 2016. The centrality of water resources to the realization of Sustainable Development Goals (SDGs). A review of potentials and constraints on the African continent. *International Soil and Water Conservation Research*, Vol. 4, No.3, pp. 215–23. https://doi.org/10.1016/j.iswcr.2016.05.004

National Planning Commission of Ethiopia. 2017. *Ethiopia 2017. Voluntary National Review on SDGs. Government Commitments, National Ownership and Performance Trends*. Addis Ababa, National Planning Commission.

Neuendorf, K. A. 2016. *The Content Analysis Guidebook*. Thousand Oaks, CA, Sage.

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J. 2014. Africa, Climate Change 2014: Impacts, adaptation, and vulnerability, Part B: Regional aspects. V. R. Barros, C. B. Fiel, D. J. Dokken, M. D. Mastrandea, K. J. Mch, T. E. Bilir, M. Charterjee, K. L. Ebi, Y. O. Estarada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Lvy, S. Mas Craken, P. R. Mastrandea, L. L. Whie (eds), *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge and New York, Cambridge University Press, pp. 1199–265.

Ntona, M. and Morgera, E. 2017. Connecting SDG 14 with the other Sustainable Development Goals through marine spatial planning. *Marine Policy,* Vol. 93, pp. 214–22. https://doi.org/10.1016/j.marpol.2017.06.020

Odusola, A., Cornia, G. A., Bhorat, H. and Conceição, P. (eds). 2017. *Income Inequality Trends in sub-Saharan Africa*. UNDP. Retrieved from http://www.africa.undp.org/content/dam/rba/docs/Reports/Overview-Income inequality Trends SSA-EN-web.pdf%0Aafrica.undp.org

Ojo, A. O. and Oluwatayo, I. B. 2016. Drivers and challenges of sustainable development in Africa. *Proceedings of The 3rd International Conference on African Development Issues 2016*. pp. 523–26. Lagos, Covenant University Press.

Oteng-Ababio, M., Melara, J. E. and Gabbay, O. 2013. Solid waste management in African cities: Sorting the facts from the fads in Accra. *Habitat International*, Vol. 39, pp. 96–104.

Population Reference Bureau. 2016. *2016 World Population Data Sheet with a Special Focus on Human Needs and Sustainable Resources*. Washington, DC, Population Reference Bureau.

Primorac, J. H. 2016. *The Big Squeeze: Global Population Pressures*. New York, IMF.

Sasson, A. 2012. *Food Security for Africa: An Urgent Global Challenge.* FAO-AGRIS

Sia, D., Onadja, Y., Hajizadeh, M., Heymann, S. J., Brewer, T. F. and Nandi, A. 2016. What explains gender inequalities in HIV/AIDS prevalence in sub-Saharan Africa? Evidence from the demographic and health surveys. *BMC Public Health*, Vol. 16, No. 1, p. 1136. https://doi.org/10.1186/s12889-016-3783-5

Singh, G. G., Cisneros-Montemayor, A. M., Swartz, W., Cheung, W., Guy, J. A., Kenny, T.-A. and Ota, Y. 2017. A rapid assessment of co-benefits and trade-offs among Sustainable Development Goals. *Marine Policy,* Vol. 93, pp. 223–31. https://doi.org/10.1016/j.marpol.2017.05.030

Takeuchi, K. and Obijiofor, A. 2011. Sustainability challenges and opportunities in Africa. *Sustainability Science*, Vol. 6, pp. 3–5.

UNDESA. 2015. *The World's Women 2015: Trends and Statistics.* New York, UNDESA. https://doi.org/10.18356/9789210573719

UNDESA. 2017. *World Population Prospects: The 2017 Revision* (ESA/P/WP/248). New York, UNDESA.

UNDESA. 2018. *2017 Synthesis of Voluntary National Reviews 2017. DSD, DESA, UN.*

UNECA. 2015*a*. *Africa Regional Report on the Sustainable Development Goals: Summary Report*. Addis Ababa, UNECA.

UNECA. 2015*b*. *Sustainable Development Goals for Southern Africa SubRegion: Summary Report*. Addis Ababa, UNECA.

UNECA. 2015*c*. *Sustainable Development Goals for the North Africa Sub Region: Summary Report*. Addis Ababa, UNECA.

UNEP-WCMC. 2016. *The State of Biodiversity in Africa: A Mid-term Review of Progress towards the Aichi Biodiversity Targets*. Cambridge, UNEP-WCMC.

UNESCO and EOLSS. 2012. *Area Studies - Regional Sustainable Development: Africa*. Vol. 2. Paris, EOLSS.

UNESCO UIS. 2017. *Women in Science*. (FS/2017/SCI/43.) Paris, UNESCO Institute for Statistics (UIS).

UNICEF. 2017. *2017 EO: Reducing Stunting in Children Under 5 Years of Age: A Comprehensive Evaluation of UNICEF's Strategy and Programme Performance. Global Synthesis Report*. Geneva, UNICEF.

UNU-IHDP and UNEP. 2014. *Inclusive Wealth Report 2014. Measuring progress toward sustainability.* Cambridge, Cambridge University Press.

Whitfield, S. 2016. *Environmental and Social Sustainability in Africa*. Rome, ISPI.

WHO and UNICEF. 2017. *Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines*. Geneva, WHO.

Wodon, Q. 2007. *Growth and Poverty Reduction: Case Studies from West Africa*. (World Bank Working Paper No.79.) Washington, DC, World Bank.

World Bank Atlas of Sustainable Development Goals. 2017. Retrieved August 5, 2017 from http://datatopics.worldbank.org/sdgatlas

World Bank. 2017. *World Bank Annual Report 2017*. Washington DC, World Bank.

Zhou, X. and Moinuddin, M. 2017. *Sustainable Development Goals Interlinkages and Network Analysis: A Practical Tool for SDG Integration and Policy Coherence*. Kanagawa, Japan, Institute for Global Environmental Strategies (IGES).

Appendices

Appendix 2.1. Search terms used in Scopus

SDG	Keywords
SDG 1	poverty; Africa
SDG 2	hunger; Africa
SDG 3	well-being; good health; Africa
SDG 4	education; quality; Africa
SDG 5	gender; Africa
SDG 6	clean water; sanitation; Africa
SDG 7	affordable energy; clean energy; Africa
SDG 8	decent work; economic growth; Africa
SDG 9	industry; innovation; infrastructure; Africa
SDG 10	inequality; Africa
SDG 11	sustainable cities; sustainable communities; Africa
SDG 12	responsible consumption; responsible production; Africa
SDG 13	climate change; Africa
SDG 14	costal; marine; biodiversity; Africa
SDG 15	land; biodiversity; Africa
SDG 16	peace; justice; institution; Africa
SDG 17	partnership; Africa

Source: Authors production

Appendix 2.2. Literature distribution from 2008 to 19 July 2017 by document type and year collected in Scopus

	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017	
Doc. type	**Qty.**	**%**	**Qty.**	**%**	**Qty.**	**%**	**Qty.**	**%**	**Qty.**	**%**	**Qty.**	**%**	**Qty.**	**%**	**Qty.**	**%**	**Qty.**	**%**	**Qty.**	**%**
Article	1 815	76.8	1 928	74.7	1 821	71.7	2 056	70.5	2 213	72.4	2 659	74.4	3 034	78.9	2 855	75.5	2 752	73.9	1 420	70.2
Book chapter	83	3.5	162	6.3	229	9.0	263	9.0	286	9.4	280	7.8	215	5.6	294	7.8	199	5.3	33	1.6
Review	153	6.5	145	5.6	145	5.7	208	7.1	184	6.0	201	5.6	204	5.3	222	5.9	243	6.5	136	6.7
Conference paper	170	7.2	196	7.6	157	6.2	206	7.1	137	4.5	195	5.5	166	4.3	202	5.3	183	4.9	52	2.6
Book	72	3.0	76	2.9	109	4.3	101	3.5	162	5.3	171	4.8	119	3.1	112	3.0	93	2.5	18	0.9
Article in press	-	0.0	-	0.0	2	0.1	2	0.1	8	0.3	8	0.2	57	1.5	40	1.1	199	5.3	345	17.1
Editorial	22	0.9	26	1.0	26	1.0	27	0.9	22	0.7	23	0.6	15	0.4	17	0.4	18	0.5	6	0.3
Note	11	0.5	12	0.5	20	0.8	16	0.5	24	0.8	15	0.4	19	0.5	21	0.6	19	0.5	5	0.2
Short survey	17	0.7	22	0.9	18	0.7	20	0.7	12	0.4	6	0.2	7	0.2	6	0.2	7	0.2	1	0.0
Conference review	6	0.3	6	0.2	4	0.2	3	0.1	3	0.1	8	0.2	6	0.2	8	0.2	9	0.2	3	0.1
Letter	6	0.3	4	0.2	5	0.2	7	0.2	3	0.1	4	0.1	4	0.1	4	0.1	3	0.1	3	0.1
Business article	7	0.3	3	0.1	5	0.2	8	0.3	4	0.1	4	0.1	1	0.0	-	0.0	-	0.0	-	0.0
Year total	2 362		2 580		2 541		2 917		3 058		3 574		3 847		3 781		3 725		2 022	

Source: Authors production

Appendix 2.3. Total documents and average annual growth rate per SDG cluster

	2008	2009	2010	2011	2012	2013	2014	2015	2016	AAGR
[1]Cluster 1	351	388	326	408	390	469	451	508	521	6%
[2]Cluster 2	986	1 155	1 161	1 293	1 314	1 540	1 884	1 716	1 734	8%
[3]Cluster 3	1 486	1 627	1 621	1 884	2 029	2 369	2 372	2 369	2 314	6%

[1] Includes SDG 2, SDG 6, SDG 7, SDG 9, SDG 11, SDG 12, SDG 14, SDG 16

[2] Includes SDG 3, SDG 4, SDG 8, SDG 10, SDG 15, SDG 17

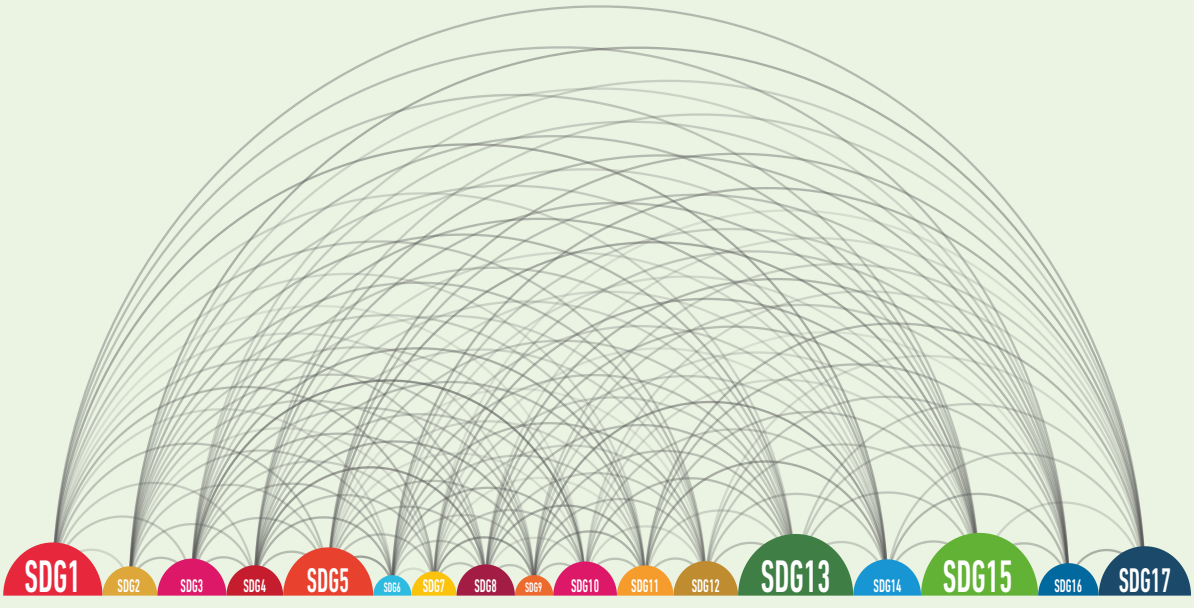
[3] Includes SDG 1, SDG 5, SDG 13

Source: Authors production

Appendix 2.4. Word cloud for each SDG based on all literature sources

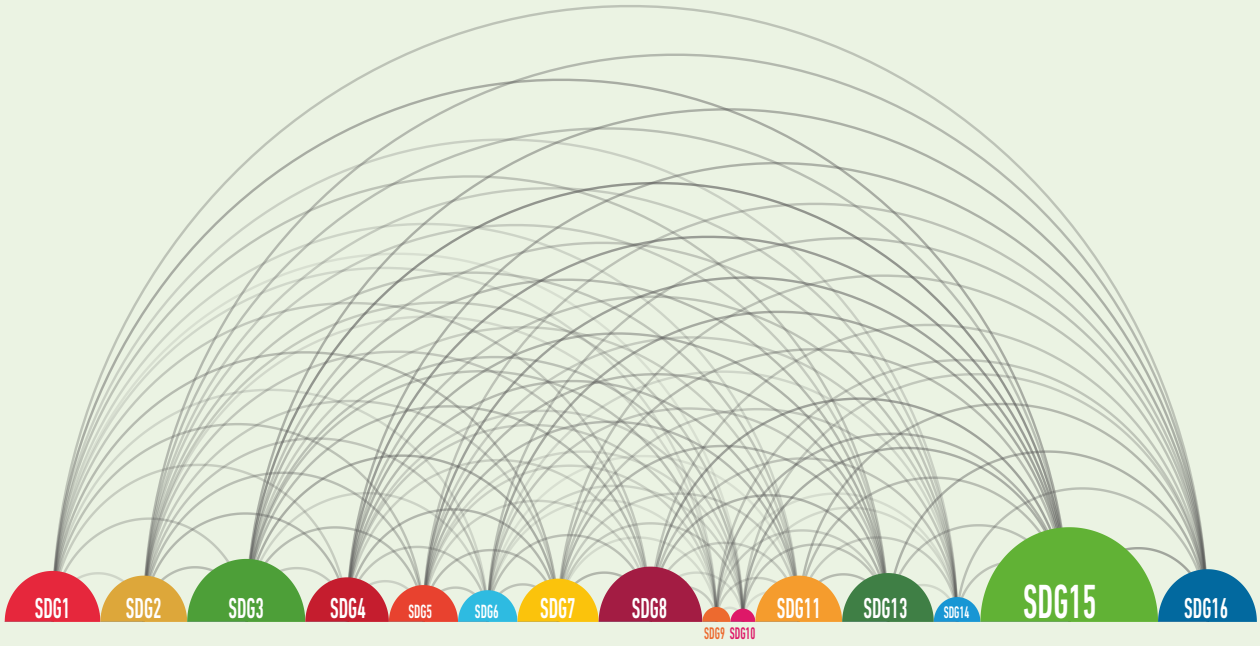
Source: UN 2015

Appendix 2.5. SDG linkages and coverage from Scopus literature source



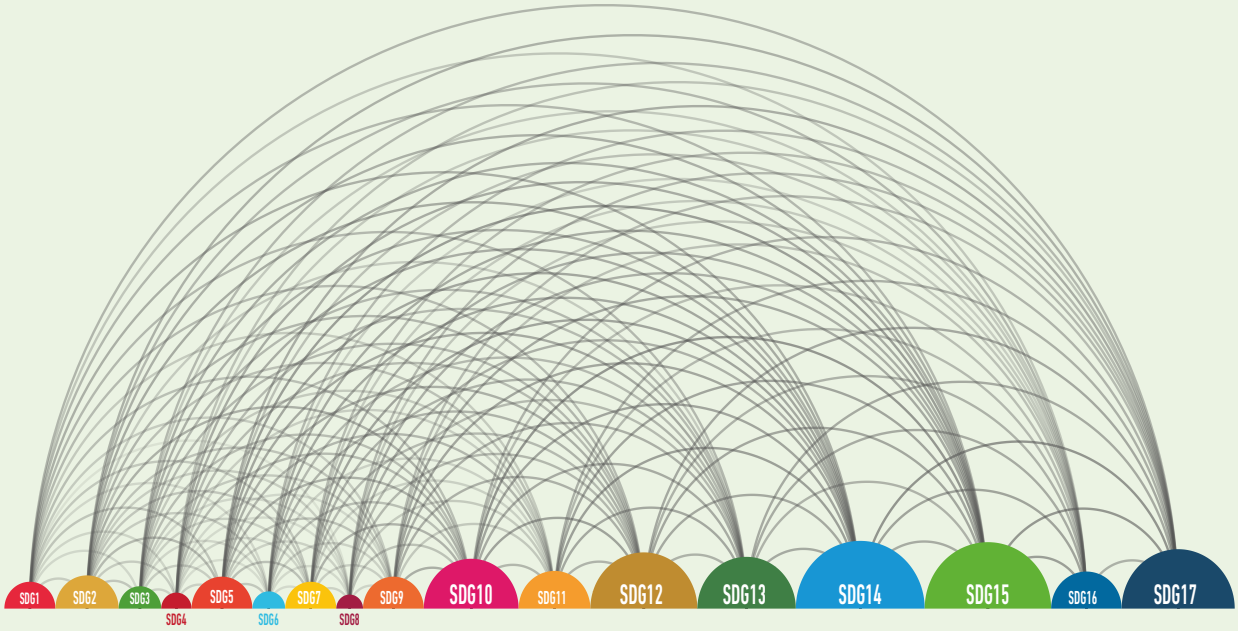
Source: Authors production

Appendix 2.6. SDG linkages and coverage from AUC literature source

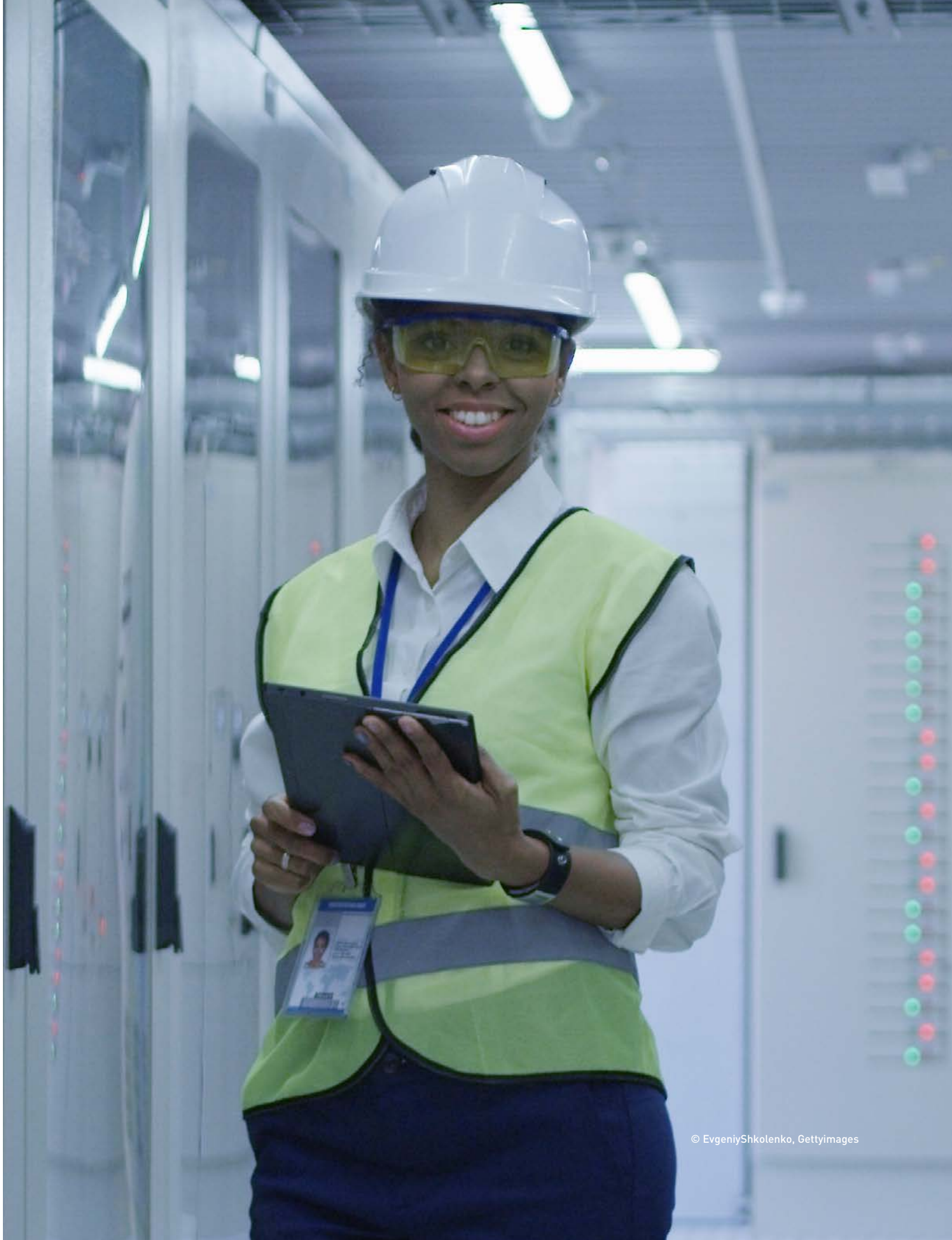


Source: Authors production

Appendix 2.7. SDG linkages and coverage from the World Bank Atlas literature source



Source: Authors production



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3

Multistakeholder engagement in innovation for sustainability in Ethiopia

3. Multistakeholder engagement in innovation for sustainability in Ethiopia

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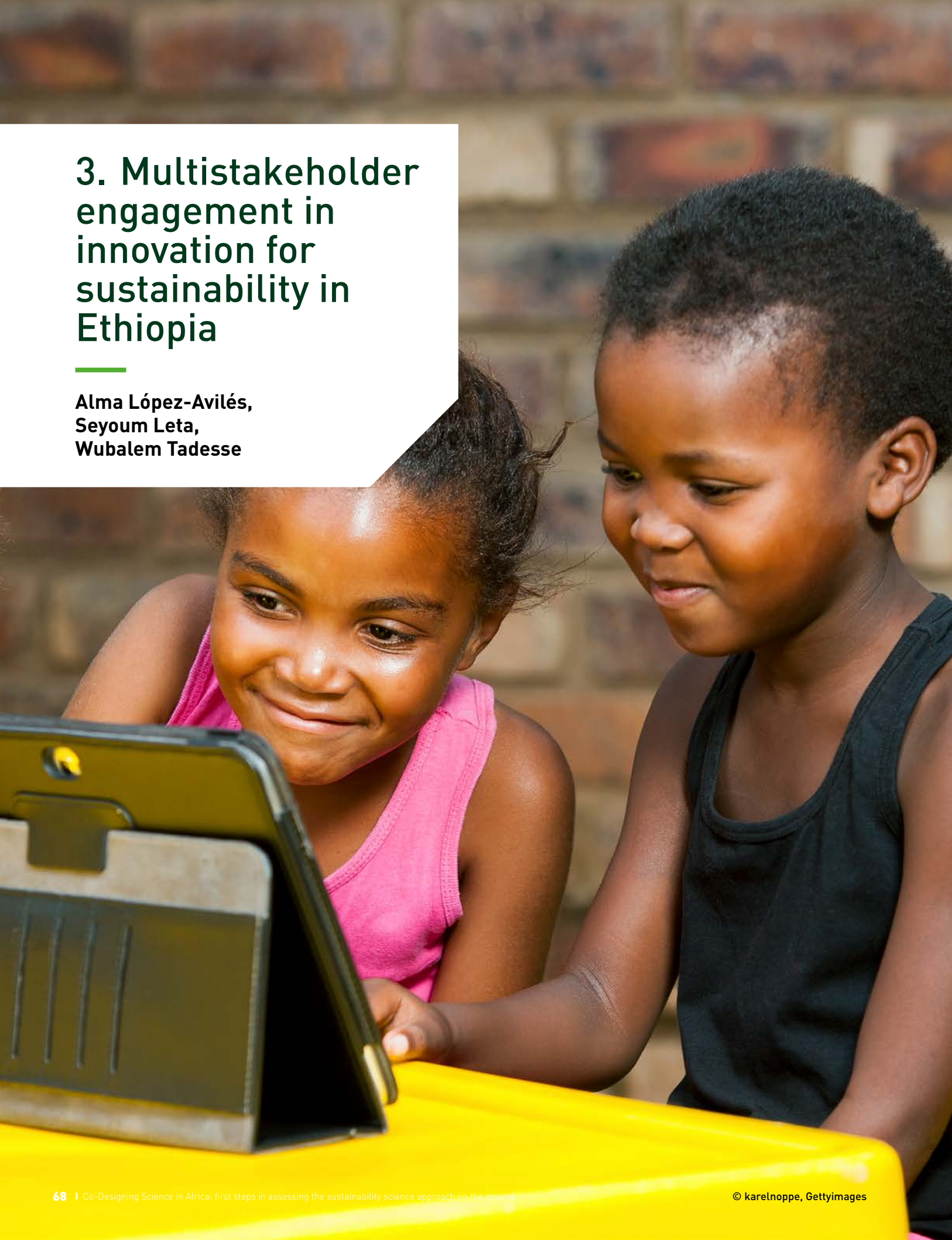
Seyoum Leta,
Wubalem Tadesse



3.1. Introduction

Ethiopia faces some serious problems and inherent tensions linked to the sustainable use of natural resources, and is confronted with the sustainability challenge of reconciling economic, social and environmental priorities. This chapter describes the nexuses between water, energy, population, land use, agriculture and other economic activities, and discusses tensions for the sustainable use of natural resources (e.g. dams constructed for hydroelectricity generation, irrigation schemes for energy crops such as sugar cane, and flowers or coffee cash-crops are seen by some stakeholders to compete directly with their traditional water use in agricultural, fishing and pastoralist subsistence practices).

To solve sustainable development problems, research and innovation, as well as cooperation and governance, have to be understood as drivers for economic development and environmental and societal well-being. The Ethiopian context provides the tools to explore the collective nature of innovation as a co-evolutionary process that results from the alignment of technical, social, political, institutional and organizational dimensions, especially when it comes to the sustainability agenda. Therefore, this chapter develops insights about the complexity of the sustainability challenge and the innovation process in Ethiopia, and outlines ways of coping with the inherent tensions across the social, economic and environmental dimensions via institutional support, governance, research, network and knowledge brokering, capacity-building and demand articulation.[1]

The revised National Science, Technology and Innovation (STI) Policy of Ethiopia has been operational since 2010 and cites innovation as the key process by which Ethiopia can build competitiveness and become a middle-income country by 2025. The STI policy emphasizes that 'the integration and cooperation among various stakeholders will be of paramount importance to realize the policy's objectives'. Thus, this chapter examines Ethiopian STI and other policies affecting sustainability; it describes how sustainability science is understood in the country, including how the engagement of multiple stakeholders is shaping innovation and its associated processes; and it presents examples of systems, services and business models that are innovative in their approach to promoting sustainable social and economic improvements.

1 Demand articulation: 'Learning processes about needs for new and emerging technologies' according to Smits (2002) and 'iterative, inherently creative processes in which stakeholders try to address what they perceive as important characteristics of, and attempt to unravel preferences for an emerging, innovation' according to Boon et al. (2011).

3.2. Ethiopia's social, economic and environmental context

The social, economic and environmental context in Ethiopia is described in this section under three distinct subheadings that correspond with the three traditional sustainability spheres or pillars. However, given the inherent interconnections and tensions between social, economic and environmental aspects, and their equal importance when aiming to achieve sustainability, these aspects are considered jointly in the discussion of the main problems linked to sustainable resource use in section 3.3 and throughout the chapter.

3.2.1. Social aspects

Population

Ethiopia's population density has been strongly influenced by the climate, water availability, access to good soils and altitude. Approximately 80% of the population reportedly lives in 37% of the total area of the country, with population densities of up to 800 persons per km^2 in the Enset (false banana) belt, and much higher densities in urban environments which accounted for approximately 17% of the total population in 2010 (Forum for Environment, 2010).

Recent estimates put Ethiopia's population somewhere between 84 million in 2011[2] and 98 million in 2014, based on the most recent United Nations projections. If the country follows its current growth rate of 3.02%, it is estimated that its population will double in the next 20 years and reach 300 million by 2050.[3] Ethiopia's children make up 55% of the population, while young people (aged 15–29) are about 30%. Approximately 84% of the country's children are engaged in activities that may be regarded as labour, including domestic jobs and work in farming and agriculture.[4] Factors influencing population growth include the situation of peace and economic growth sustained in the last three decades, early marriage, lack of contraceptive use, and improved child and general mortality rates with the consequent increase in life expectancy (Forum for Environment, 2010).

However, despite improvements in access to education, health parameters and standard of living illustrated by the Human Development Index (HDI), which increased from 0.284 to 0.442

2 http://data.un.org/CountryProfile.aspx?crName=ethiopia
3 http://worldpopulationreview.com/countries/ethiopia-population
4 www.unicef.org/ethiopia/protection.html

between 2000 and 2014,[5] Ethiopia is still in the lowest human development category, ranking 174 out of 188 countries (UNDP, 2015), and approximately 10% of Ethiopians are chronically food insecure – up to 20% can go hungry in drought years (UNESCO-Sida, 2017).

Other indicators of poverty, health, access to nutritious food and sanitation, education, gender equality etc. are collected in the Sustainable Development Goals (SDG) Index and Dashboards Reports (see United Nations Sustainable Development Solutions Network: UNSDSN, 2017 and Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network: SDGCA&SDSN, 2018 reports). The SDGCA&SDSN (2018) data source illustrates, for example, that the percentage of people on $1.90/day in Ethiopia has decreased from 33.7 per cent of the population in 2012, to 16.4 per cent in 2018. Examples of improvements in nutrition and health are shown via indicators such as prevalence of stunting (low height-for-age) in children under 5 years of age which has decreased from 57.4 per cent in 2000 to 40.4 per cent. Healthy life expectancy at birth has increased from 51.2 years in 2000 to 64.8 years.

Access to improved sanitation facilities has risen from 19.1 per cent of the population in 2008 to 28 per cent in 2015, access to improved water sources has also increased nationally from 43.9 per cent of the population in 2008 to 57.3 per cent in 2015 according to the report by UNSDSN (2017). There are geographical differences also, with for example, 86 percent of the urban population having access to improved (piped) water in 2015, up from 83.3 per cent in 2000 according to the same source. Expenditure on research and development accounts for a small proportion of the national Gross Domestic Product (GDP), however this has increased from 0.17 per cent of GDP in 2005 to 0.6 per cent in 2013 according to UNSDSN (2017). Information on research priorities and donors can be discerned from the list of programmes in **Table 3.1** (given in section 3.5.2.).

Education

The situation in Ethiopia in terms of youth's access to education is illustrated in **Figure 3.1**. Only around 7% of Ethiopian youth (aged 15–24 years) have completed primary education, while 55% have attended some, but not completed, primary education. Significantly, 22% of the youth have no formal education at all. Only 11% have some secondary level education, but only 5% complete secondary education to progress into higher education.

Moreover, there are important differences in access to school for children and youth based on gender, family income and location (urban versus rural), as reported by the Education Policy and Data Centre (EPDC, 2014).[6] More youth, both boys and girls, are 'out of school' as they grow older, but the situation is worse for girls, with the percentage of 'out of school' becoming higher for girls than boys after the age of 14 years, increasing sharply from 31% for 7–14 year-old girls to 44% for 15–18 year-old girls (data from EPDC, 2014). Furthermore, data from this source also indicate that the poorer the child is, the less likely he/she is to be in school, especially in rural areas.

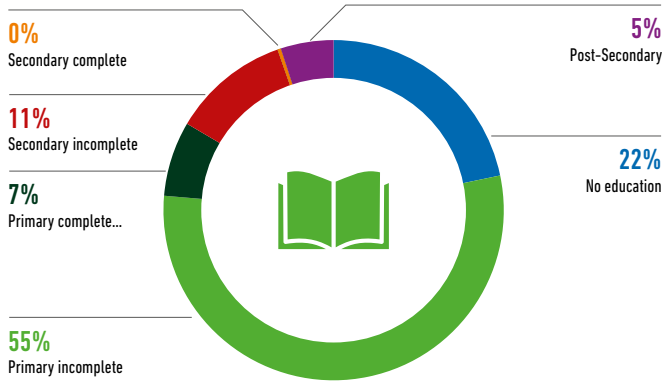


Figure 3.1. Youth educational attainment in Ethiopia.
Source: EPDC, 2014.

Gender equality

Despite the progress made in past years, Ethiopia still experiences some of Africa's worse gender disparities, as reported as part of a project by UNESCO-Sida (2017). Women and girls are disadvantaged compared to boys and men in literacy, health, human rights and livelihoods (e.g. women often lack control of savings, productive assets, access to market and thus, women do not qualify for agricultural credit). Women have a lower status than men in Ethiopian society, lack social support networks and access to family planning and reproductive health services, and have one of the world's highest maternal mortality ratios (590–675 maternal deaths per 100,000 live births).

Morbidity rates are 75.5% for women, against 25.5% for men, and adult HIV prevalence is 1.9% for women, against 1% for men due to poverty, poor nutrition, limited healthcare, financial constraints, cultural beliefs and harmful traditional practices (e.g. genital cutting and child marriage). Approximately 27% of women of reproductive age are chronically malnourished, especially in rural areas,[7] but they still participate in economic life with the majority being unpaid family workers (*c.* 75%) or self-employed in informal jobs (*c.* 25%).

5 http://hdr.undp.org/sites/default/files/nhdr2015-ethiopia-en.pdf

6 http://www.epdc.org/sites/default/files/documents/EPDC%20NEP_Ethiopia.pdf

7 https://www.unicef.org/ethiopia/nutrition.html

3.2.2. Economic aspects

In a recent assessment of Ethiopia's economy for the decade 2004–2014, the World Bank (2016) states that it is 'amongst the world's fastest growing economies' and that this growth has been stable over the past decades, with official data indicating that real GDP growth averaged 10.9% in 2004–2014. Ethiopia's growth strategy is inspired by the East Asian development state model of intervention in all economic sectors. However, in the Ethiopian model, agriculture has been the most prominent sector driving economic growth until services and construction took over in recent years, keeping up with private demand as the country moves towards a market-based system, as shown in **Figure 3.2**. Agricultural development has been helped by public infrastructural development of clean energy, roads, railways and telecommunications (World Bank, 2016).

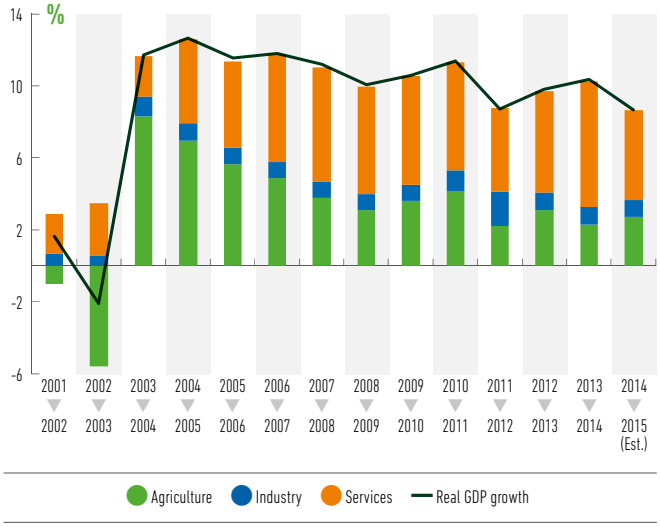


Figure 3.2. Ethiopia's GDP growth and contribution per sector.
Source: IMF, 2015

Agriculture and forestry sectors

According to the World Bank (2016), Ethiopia is rich in biodiversity and an ecosystem service linked to forests, and is endowed with fertile land suitable for agriculture purposes, including sustaining one of the largest livestock populations in Africa. Forestry and raising livestock are considered within the agriculture sector and so are their contributions to GDP in **Figure 3.2**.

However, the agriculture sector is dominated by small-scale farmers who practise rain-fed mixed farming by employing traditional technologies, and adopting a low-input and low-output production system. Despite this situation, agriculture is the largest sector in the economy, accounting for over 50% of GDP and employing over 85% of the labour force, thus determining the growth of all other sectors. Within the sector, crop production makes up 60% of output and livestock accounts for 27%, with other areas contributing 13% of the total agricultural value added.

Ethiopia's cereal production increased by 249% in the 20 years before 2014, as a result of improved yields and an 88% expansion in crop areas (Franks et al., 2017). Increased grain demand of up to 162% is projected for the period 2010 to 2050 and, according to Ethiopia's Climate Resilient Green Economic (CRGE) strategy of 2011, in addition to improved yields, agricultural land will need to expand by nearly 4% (550,000 ha) per year in order to meet the sector's growth targets. If everything remains as it is presently, up to 55% of the required land expansion could be at the expense of forests and associated biodiversity and ecosystem services (Franks et al., 2017).

Diversifying grain and coffee production in Ethiopia by increasing the production of khat (*Catha Edulis*, a stimulant drug chewed in Ethiopia and neighbouring countries) has been reported in the last 16–17 years as a 'livelihood strategy to compensate for declining household income linked to food crops and coffee' (Belwal and Teshome, 2011). According to this source, Ethiopia's coffee exports dropped from 70% to 35% of total export earnings in 2000, while the official income export from khat increased by 13%. Land for khat farming has reportedly increased by 160% between 2001 and 2014, and khat is being farmed by approximately 3.1% of Ethiopian farmers in their landholdings. However, it should be noted that this land-use change only amounts to a small increase in area (i.e. from 96,000 ha in 2000 to 163,000 ha in 2007), and also that khat is grown in land considered infertile for food crops and under variable rainfall with minimum risks and maximum economic returns, according to Adimassu et al. (2014). The increase in khat cultivation also has to be seen in the context of the total surface area of Ethiopia, which is 110.4 million ha, and the total area of agricultural land within the country, which is 35.6 million ha.[8]

Issues of deforestation, overgrazing, soil erosion, as well as the pressures resulting from higher demand for grain, as well as land-use changes linked to land leased to agro businesses in the south and west of the country, and any issues of displacement of indigenous communities (e.g. in the Omo Basin and the Gambella region) are examined in the following section under 'Environmental aspects'.

8 https://tradingeconomics.com/ethiopia/agricultural-land-%-of-land-area-wb-data.html

Energy sector

The majority of Ethiopians (*c.* 83%, based on data from 2010)[9] live in rural areas where only approximately 5% of the population have access to modern energy services such as electricity, compared to *c.* 85% of the urban population. Charcoal is the predominant source of energy for cooking in urban households, which also rely on biomass (wood, cattle dung and agricultural waste). Thus, bioenergy has been the major source of energy, with traditional biomass sources providing 94% of the total energy requirements, which is strongly linked to the deforestation problems analysed in the following section. Petroleum (kerosene) and electricity are progressively meeting more of the energy demand linked to a growing population and the emergent industrial and service sectors. Approximately 48% of towns and villages were connected to the grid as of July 2012.[9] In rural areas, only 0.2% and 1.2% of households use kerosene or charcoal respectively, while the rest depend on biomass (data from 2011).[9]

The CRGE strategy (CRGE, 2011) considers energy, together with agriculture, as one of the main pillars for economic development in Ethiopia, and the Government has made energy generation a priority for the country's economic and industrial development. The CRGE strategy focuses on developing carbon-neutral energy sources in the country, namely: hydroelectricity, geothermal, biofuels and wind power.

Thus, since the early 2010s, the national government has channelled resources to invest in producing the necessary renewable energy in order to achieve the ambitious goal of becoming a middle-income country by 2020–23 (GTP, 2011). The main investments are large-scale hydropower dams, such as the Grand Ethiopian Renaissance Dam being built on the River Abbay (Blue Nile), and other electricity-generating dams in the Omo-Gibe, Baro-Akobo, Tekeze and Mereb river basins also under construction or planned.[10] The Renaissance Dam is being built near the border with Sudan, and is designed not for expanding irrigation and improving agricultural outputs, but with the aim of generating hydroelectricity to export, and to drive economic development through its emergent industrial and service sectors.

Hydropower represents *c.* 92% of the total energy mix used to generate electricity, while thermal energy comprises *c.* 7% (data from 2011),[9] but only part of the potential solar, wind and geothermal energy of the country has been developed. There is also an incipient proliferation of biofuels (jatropha and sugar cane for ethanol) and wind-energy sources encouraged by the government, with other alternatives being piloted too. As an example, a 50-Megawatt (MW) waste-to-energy plant is being constructed on a 50-year-old open dump in Addis Ababa, which is also in line with the CRGE's strategy for carbon-neutral development. This facility will process 350,000 tons of residual municipal and commercial solid waste per year, using high efficiency waste combustion technology with energy recovery, which will manage the waste in agreement with the target for sustainable waste management,[11] while generating electricity for 30% of the city's households.[12]

Transport, industrial and building sectors

As indicated in **Figure 3.2**, the service sector has been increasing its contribution to Ethiopia's economy since 2003, while the industrial sector, on the other hand, remained stagnant for several years with a modest contribution to GDP of less than 10%. However, this sector has been driven by the state since 2015, via policies to attract internal and foreign industrial investment and the development of state-sponsored industrial parks, such as the Hawassa Park, focused on textile industries.

The transport and building subsectors have also grown in the last decade to meet the country's demand for new roads and public transportation systems, as well as the need for housing, hotels and offices associated with an increasingly thriving service and business economy in cities such as Addis Ababa, Bahir Dar, Hawassa and Arba Minch.

The transport sector has been a priority of the Ethiopian government since the 2000s, as the infrastructure of roads and rail had been neglected in Ethiopia during years of political instability and war. A large number of roads are under construction but the country still has large areas disconnected, making transportation of people and goods difficult, especially in rural areas and during the rainy season when dirt-roads can become impassable. Furthermore, the port of Djibouti is the main point for entry of goods, but the port limitations, e.g. lack of parking space for trucks, slow the movement of merchandise to and from Ethiopia.[13] The railway to Dire-Dawa nearby has recently been upgraded, which will help to improve the situation.

Addis Ababa, with its rapid population growth and physical expansion, is the most extreme example of inefficient and poor-quality public transport, a situation which also affects other

9 https://www.reeep.org/ethiopia-2014

10 http://www.un.org/esa/agenda21/natlinfo/countr/ethiopia/natur.htm#freshw

11 http://www.skyscrapercity.com/showthread.php?t=1911946 published on 8 April, 2016 and http://cleanleap.com/ethiopias-mountain-waste-becomes-new-energy-source published on2 July, 2015.

12 https://waste-management-world.com/a/video-50mw-waste-to-energy-plant-part-of-sustainable-development-plans-in-ethiopia

13 http://www.ifsmrc.org/sites/default/files/journals/pdf/8.%20AIJRM%202319JJ14%20Dr.%20Anbalagan%20Dr.%20Kanagaraj%20Auto-Analysis.pdf

cities. As a result, Addis Ababa Administration developed the Transport Plan (2007) and Transport Policy (2011) to promote city buses, minibus taxi services and the Light Rail Transit System along the main corridors into and across the city to alleviate congestion and facilitate the movement of goods and people in Addis Ababa (Meshesha Fenta, 2014).

3.2.3. Environmental aspects

The review of Ethiopia's environmental baseline situation by Forum for Environment (2010) helps to provide the context for the country up to 2010 and is referred to throughout this section.

Water

Water resource availability, water pollution, and access to safe water and sanitation are concerning issues in Ethiopia. The country's water resources are unevenly distributed geographically and also the large intra- and inter-annually seasonal variability of rainfall limit water resource availability (Lal Kansal et al., 2014).

Furthermore, Ethiopia's demand for water is steadily increasing as a result of population growth and rapid urbanization, industrialization and agricultural developments linked to irrigation of vegetable, flowers and energy crops, plus increasingly erratic rainfall seasons. As described above, the majority of the population in Ethiopia lives in rural areas in the fragile highland ecosystems, growing crops that are mainly rain-fed, with recent initiatives to build microdams for irrigation of crops (some of them energy crops) and a number of large-scale hydrodams for electricity generation (see energy section above), which come into conflict with the traditional water uses of fishermen, pastoralists and subsistence farmers.

Photo 3.1. The Blue Nile Falls during the dry season (photographed in February 2012). The Blue Nile River upper catchment collects highly seasonal flows from tributaries draining into Lake Tana, from where the river flows in a large loop around the north – north-west Ethiopian highlands and into Sudan. The Grand Ethiopian Renaissance Dam is being built in the Blue Nile near the border with Sudan and it will be the largest hydroelectric power plant in Africa when completed. The Nile Basin Initiative has been fundamental in the last 20 years in discussions and reaching agreement between stakeholders from the ten member countries (Ethiopia, Sudan, Egypt, Tanzania, DR Congo, Burundi, Rwanda, Uganda, Kenya and South Sudan, plus Eritrea participating as an observer) for the fair management of water resources in the Nile Basin.

In the case of Lake Haramaya, the drop in water volumes is threatening the supply of water to the city of Harar – this is reportedly the result of water abstraction for vegetable and flower irrigation schemes, as well as drainage for crop cultivation, urbanization and industrialization. Drainage of rivers and lakes for farmland are also contributing to flooding and siltation.

Reductions in the water volume of the above lakes have resulted in increased salinity and concentration of nutrients, particularly nitrogen and phosphorus, which result in eutrophication and have led to the loss of fish, bird species and other fauna and flora linked to the wetlands. In addition to the loss of biodiversity on surface water bodies, eutrophication is also affecting the groundwater resource, for example in the Wonji sugarcane plantation area (Forum for Environment, 2010). The expanding intensive floriculture sector in Ethiopia is also raising concerns about the large amounts of waste and water needed – compared with conventional farming – and also about environment and human health in relation to increased levels of nitrates on soils and water bodies as a result of the intensive use of chemical fertilizers and pesticides. Ethiopia is the second-largest rose exporter in Africa and the sixth in the world, mainly through foreign investment. This situation is driving improvements in environmental legislation, and the regulatory and enforcement systems of Ethiopia (Getu, 2009).

However, regulations and guidelines need to be tightened in relation to weak water quality standards for industrial and agricultural effluent discharges, and unmanaged sanitation and water contamination linked to urbanization. Furthermore, monitoring systems and enforcement mechanisms need to be implemented, for which more enforcement capacity is needed.

Biodiversity and ecosystem services

Ethiopia is endowed with 10 main ecosystem types, and 18 major and 49 minor agro-ecological zones that are inhabited by a great diversity of animal, plant and microbial life, making the country unique in terms of biodiversity (EBI, 2015). In terms of vegetation, this ranges from tropical rain and cloud forests in high plateaus and mountains to the desert scrubs of the eastern lowlands, and parkland agroforestry on the central plateau (Teketay et al., 2010). Due to the country's rich biodiversity, Ethiopia is considered the 5th most diverse country in Africa (Tadesse, 2004). There are 75 breeds of cattle, sheep, goat, camel (dromedary), equines and chickens, and 6 species of honey bee. There are also large numbers of wild mammals, birds, reptiles, fish and amphibians, and invertebrate species, with several dozen in each kingdom being endemic to the country. Further to this wealth in biodiversity, it is believed that Ethiopia is also rich in microbial genetic resources (EBI, 2015).

However, Ethiopia has 6 critically endangered, 23 endangered and 70 vulnerable species of wild fauna on the International Union for Conservation of Nature's Red List of Endangered Species (IUCN, 2014), and some of these endangered species, such as the walia ibex (*Capra Walia*), have very restricted distribution (EBI, 2014). The biodiversity and the ecosystems of wetlands, rivers and lakes along Ethiopia's Great Rift Valley are at risk, according to Forum for Environment (2010). According to this source, lower lake levels in Lakes Abiyata and Ziway, and the complete disappearance of Lake Haramaya, have affected ecosystem services such as fisheries, thus negatively impacting on the livelihoods of local communities.

Forestry

Forest resources in Ethiopia comprise a total of 59.7 million ha covered by woody vegetation, among which approximately 7% is high forest, 49% woodland and 44% shrubland or bushland. Natural high forest is concentrated mainly in Oromia (62.5%), Southern Nations, Nationalities and Peoples (19%) and Gambella (9%) regions to the north-west, west and south-west of the country. The largest areas of woodlands and shrublands are located in Somali (33%), Oromia (32%) and Amhara (10%) regions – now federal states (WBISPP, 2004).

The forestry sector of Ethiopia makes a direct contribution to the national economy through wood and non-wood forest products. It also plays an important role in maintaining the ecological balance and provides the means for livelihood diversification for many rural communities in parallel with other agricultural activities. The large land extension of Ethiopia, its altitude, soil and climate conditions are suitable for forestry development (Teketay et al., 2010) and as indicated in previous sections, the majority of the country's energy sources come from biomass from forests, woodland and shrubland. These also provide valuable ecosystem services (e.g. wild coffee, fodder for livestock, honey, shea butter, timber, forest food and traditional medicinal plants).

Furthermore, some forests and shrublands help conserve biodiversity as well, as they help to regulate the climate and store carbon stocks; thus, they are critical in combating climate change, and also land and water resources degradation in Ethiopia. Even forests of non-native eucalyptus species can help to protect soils from erosion caused by intense rainfall, and have been found to host high herbaceous species richness, and to foster natural regeneration of indigenous woody species such as *Juniperus procera* and *Podocarpus falcatus*, e.g. at Entoto natural park north

of Addis Ababa. Thus, well-managed eucalyptus species can help to restore degraded forestlands; eucalyptus growers favour the species because it is fast-growing and offers a high yield per unit area, it is easy to manage and there is good demand for its wood at reasonable prices, making it difficult for eucalyptus to be substituted with equally productive and adaptive species.

However, according to Forum for Environment (2010), based on data of the spatial distribution of forests, woodlands and bushlands compiled from various sources dating back to 1994, Ethiopia has been losing around 140,000 ha (1%–1.5%) of forest each year since 1990, including natural forests within the protected National Forest Priority Areas. Tadesse and Desalegn (2013) corroborate the picture of intense forest degradation in Ethiopia, and indicate that for centuries forests have been used for fuelwood and have been cleared to open up land for agriculture and grazing, leading to shortages of fuel and construction wood, destruction of habitats, loss of biodiversity, soil erosion and desertification.

Despite this negative picture, there are recent initiatives to rehabilitate natural vegetation and wildlife, to maximize the potential for forest and bushland-based ecosystem services, and to improve institutional and legal arrangements (Forum for Environment, 2010).

Photo 3.2. View of the Highlands near Adwa, in Tigray, northern Ethiopia. Terracing of steep hillside slopes using local stone and soil walls is common in the Highlands in order to prevent soil erosion and allow cultivation of staple subsistence crops in parallel with forestry activities. Sustainable sources of energy are being promoted in Ethiopia, including hydropower generation and other carbon-neutral sources such as geo-thermal, solar and wind. However, biomass remains the main source of energy at domestic level in rural Ethiopia, and deforestation and land degradation remain as major concerns in the sustainability debate in the country.
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Land degradation

On land degradation and management, the review by Forum for Environment (2010) indicates that the situation is concerning in Ethiopia as a result of the demand for more fuel and land to feed an unprecedented growing population. This has led to cultivation in marginal land with lack of manure for fields and deforestation, as described in the previous section.

Furthermore, the loss of topsoil and nutrients is linked to Ethiopia's seasonal rainfall patterns and sparse vegetation coverage, which can result in seasonal flooding, landslides, and soil and bank erosion. On the other hand, the dry seasons are often extended, and recurrent droughts gravely affect traditional smallholder subsistence farming and pastures. Ethiopia's vulnerability to climate change impacts directly on water resources, agriculture and food security.

Climate variability – not enough rainfall in both the main and short rainy seasons, and the short rainy season arriving late or missing in some years – has led to poor crops and food shortages in some parts of Ethiopia since at least the 1970s. Given that the country's economy relies heavily on the sensitive agricultural sector, the Government of Ethiopia is trying to resolve land degradation problems by promoting sustainable land management (SLM) practices. However, according to Forum for Environment (2010), rainfall is reportedly more erratic, and both droughts and floods are more frequent, which is impacting agricultural production and food security. Thus, the country is in a 'vicious downward cycle of land resources degradation and poverty' that leads to Ethiopia receiving the largest share of annual food aid in Africa. Approximately 10% of Ethiopians are chronically food insecure and 20% go hungry in drought years (UNESCO-Sida, 2017).

Climate change

According to the Agriculture Status Report (AGRA, 2014), 'Africa's vulnerability to climate change is exacerbated by poorly developed infrastructure and policies related to water and land'. Vulnerability will be greater in semi-arid areas where rainfall, and thus crops, are already unreliable, and in areas such as the Ethiopian highlands where rainfall and runoff will result in more extensive and severe flooding (IPCC, 2012; CDKN, 2012). The review by Forum for Environment (2010) reports that climate change impacts are expected to aggravate existing challenges in Ethiopia. In addition to changes in the rainfall patterns affecting water availability and land degradation, higher temperatures are expected to reduce agricultural production, which in turn will impact on food security and income. Atakure (2012) identified that increases in temperature are already having as much impact

on crop yields as lack of rainfall or changes in the seasonality of rainfall in the Ethiopian highlands. Increased temperature and the distribution of rainfall are also reportedly affecting health, with malaria increasingly prevalent in over 75% of the country and 50 million people at risk.

There are some recent efforts to downscale climate change models and impacts to Ethiopia, such as the recent work by Sorecha (2017). In order to project the impacts of climate change on the Lake Haramaya's catchment for the coming thirty years (2020–2050), Sorecha built on 34 years of rainfall, maximum and minimum temperature baseline data from the National Meteorological Agency (NMA) of Ethiopia, and downscaled projected rainfall and temperatures, using five climate models under two emissions concentration pathways.[14] Results from this study indicate that the annual mean rainfall in the eastern highlands will increase, but the annual and seasonal mean temperatures are projected to increase for the period 2020–2050 by as much as 0.68 °C compared to the baseline temperature of 24.73 °C in some scenarios. Despite higher water inputs in the catchment, higher temperatures mean higher evaporation rates, and this may impact on crop production.

In terms of greenhouse gas (GHG) emissions, the power sector, as well as the industrial, buildings and transport sectors, each account for less than 3% of the total GHG emissions of Ethiopia, while the agriculture (mainly livestock-rearing) and forestry sectors combined are the main sources of emissions in the country with *c.* 88% of the total GHG emissions. These are split as 51% and 37% respectively, according to the CRGE strategy (CRGE, 2011).

Urban settings

Similarly to other developing countries, in Ethiopia, urban and rural environments are clearly differentiated and main sustainability issues such as pollution and overcrowding affect cities more acutely than rural areas. Addis Ababa, and increasingly other fast-expanding Ethiopian cities, represents the extreme sustainability challenges affecting the country's urban and peri-urban settings.

For example, although sanitation is a problem in rural areas too, the concentration of people in and around the city of Addis Ababa means that poor sanitation and its associated health risks are pressing issues. These are worsened by uncontrolled discharges to air, land and water from industries and businesses, thus access to a safe supply of water, uncontaminated land, housing and fuel for cooking in cities are key concerns. Regassa et al. (2011) report that, based on Environment Development Agency (ENDA) data from 1999, Addis Ababa had a sewerage system designed for 200,000 households but only covered 6,000 households at the turn of the millennium. It is estimated that approximately 30% of Addis Ababa's households have no sanitation facilities, while the proportion in other urban areas is approximately 50% (Forum for Environment, 2010). This source also reports that despite recent improvements in health and sanitation, including better sewage coverage and infrastructure, diarrhoea from water-borne diseases kills more children under 5 years of age than any other infection, and chronic diarrhoea still affects all urban populations in Ethiopia.

Solid waste management is also a problem in most cities, including Addis Ababa, with only some communities and households receiving a solid waste collection and treatment service, due to the lack of resources available to local governments. This results in too few staff, waste collection containers, trucks and dumping sites (Regassa et al., 2011).

In relation to air pollution, since the main sources of energy for cooking continue to be biomass and kerosene even in urban areas, indoor air pollution still affects the health of women and children in particular.

Photo 3.3. illustrates various aspects crucial to the sustainability debate in Ethiopia. It shows a woman cooking in a typical rural household depending on unsafe and unreliable water and scarce biomass supplies for cooking. Deforestation and land degradation are major concerns in Ethiopia, and women and girls are the household members most burdened with wood and water collection chores. This highlights the need to consider gender equality in the wider discussion about sustainability in the country.
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The transport network and old fleet of vehicles are the main contributors to air pollution in urban areas, with the number of vehicles entering Ethiopia reportedly growing at 20% but more

14 BCC-CSM1-1, CSIRO-Mk3-6-0, HadGEM2-ES, MIROC-ESM, MIROCESM-CHEM, and MIROC5 under two Representative Concentration Pathways (RCPs): RCP4.5 and RCP8.5.

than half of vehicles on the road being more than 20 years old (Forum for Environment, 2010).

Industrial activities have also traditionally concentrated around the capital city, contributing to growing numbers of people migrating from rural areas in search of better opportunities in education and employment. This pattern is being replicated in other expanding cities such as Hawassa and Arba Minch (in SNNP), Adama (Oromia), Bahir Dar (Amhara) and Mekele (Tigray), but the population in Addis Ababa still makes up to 30% of the country's total urban population[15] and is concentrated in uncontrolled urban slums and squatter settlements in and around the city and adjacent industrial areas.

3.3. Key sustainability challenges in the use of natural resources

With one of the fastest growing populations in the world, half of which is aged 15 years or younger, most Ethiopians (approximately 80%) live in rural areas in the central and northern highlands, where population growth and poverty are much higher than in urban areas (UNESCO-Sida, 2017). Access to education, jobs and health facilities is limited in rural areas, thus urban migration in search of opportunities has been taking place for decades in Ethiopia. Modernization, urbanization and modest industrialization took place under the Emperor Haile Selassie in the 1950s and 60s in Addis Ababa and its peri-urban areas to the south. During the Marxist period since 1974 and the guerrilla warfare that ended the regime in 1991, development stalled. In the last 26 years since the end of the war against the Marxist dictatorship, developments in agriculture, transport infrastructure, industrialization and urbanization in Addis Ababa and other secondary cities have accelerated, but pollution and the pressures on the environment and on natural resources have also increased, thus threatening the sustainability of ongoing development.

Even though agriculture is Ethiopia's most economically important sector, agricultural expansion is the most significant driver of deforestation, land degradation and biodiversity loss. Land tenure in much of the territory, especially in the Highlands, is in the form of family subsistence plots that are divided further for successive generations. Cattle raising coexists with subsistence rain-fed agriculture but there are few alternative or simultaneous economic activities available to rural communities to compensate for a year of bad agricultural yields or drought. Access to markets is poor in many rural areas, despite road infrastructure progressively developing.

The unprecedented population growth is linked to the depletion of natural resources such as water and biomass, and to the extension of agriculture to the detriment of forests and natural ecosystems. Deforestation and the lack of vegetation cover combined with heavy rainfall and highly erodible soils result in land degradation in many parts of the country. Soil erosion has been linked to low crop productivity for decades, especially in the fragile ecosystems of the steep Highlands, where a large proportion of Ethiopians live.

Forests and woodlands provide biomass for cooking for the majority, including in the cities, and animal dung is also used as fuel instead of being used as fertilizer that would help to produce better crops. The reliance on increasingly scarce wood and charcoal as fuels for cooking means that obtaining wood fuel involves walking progressively longer distances, further away for many communities. Similarly to collecting water, it is mostly women and girls who carry the burden of walking longer distances to find and transport wood. This impacts on their health and reduces the time spent by women and girls in school, farming or engaging in other productive activities, thus perpetuating gender inequalities.

Furthermore, given that Ethiopia's agriculture is mostly rain-fed, agriculture is the sector most likely to be affected by climate change and to impact the largest number of people, as smallholder farmers account for 95% of gross agriculture production, and 60% of farms in Ethiopia are less than 1 ha in size (CSA, 2015). Spring and summer rains have already declined by 15–20% since the mid-1970s in the southern, south-western and south-eastern parts of Ethiopia (Franks et al., 2017), and climate change-related hazards expected to affect Ethiopia include more frequent and severe droughts, floods and increased temperatures.

In regions to the east and north-east (Somali and Afar regions), and to the south (e.g. Omo valley), there are nomadic pastoralist communities dependent on the availability of grazing pastures, shrubs and water resources. These communities and their livelihoods are some of the most vulnerable to climatic conditions of drought and flash flooding, as well as inappropriate water resource and river catchment management.

Therefore, when considering the nexus of population-agriculture (food)-environment, land degradation and loss of biodiversity resulting from over-farming, over-grazing and deforestation linked to biomass energy supply, all have to be seen in relation to

15 https://www.researchgate.net/publication/256035582_Urban_Development_in_Ethiopia_Challenges_and_Policy_Responses, and http://unhabitat.org/wp-content/uploads/2014/07/Ethiopia-National-Report.pdf

the pressures of a growing population in Ethiopia. Furthermore, a changing climate poses a further threat to land that is already widely degraded, and this can lead to further food and water insecurity among the most vulnerable communities in some parts of the country.

In trying to provide alternatives to biomass energy, hydropower generation and investment in biofuel and biodiesel production are being encouraged by the government. Damming rivers for irrigation and hydroelectricity generation has accelerated in the last decade in response to Ethiopia's effort to produce electricity for domestic and industrial supply that will help to achieve the country's ambition for carbon-neutral development. However, the proliferation of sugar cane and jatropha for ethanol has raised debate about the amount of arable land and water used to grow energy crops versus food crops. Furthermore, building large dams can displace communities from their lands (e.g. pastoralists in the Omo-Gibe basin in Southern Nations, Nationalities and Peoples – SNNP), can present technical, political and financial difficulties, can contribute to loss of biodiversity, and can also be linked to health challenges related to unmanaged sanitation and water contamination, flood risk, and the spread of water-borne diseases such as schistosomiasis and malaria.

As a result, complaints about the construction of hydro-dams and irrigation schemes for biofuel and cash crops for export (e.g. flowers, coffee) have become more common in regional states such as Oromia and SNNP. This has to be seen in relation to land grabs and limited water resources, and the view of some stakeholders that large dams and irrigation schemes are in direct competition with their traditional agricultural, fishing and pastoralist subsistence practices.

Similarly, the building sector and the emergent industrial sector are being observed by regulators in relation to environmental impacts on land, water and air, as well as on natural resource use (e.g. geophysical resources such as sand, gravel and cement for buildings and roads, and water used by industry). Increasingly, various stakeholders speak about the need for regulation in water abstraction and allocation for various competing uses (e.g. food, energy and cash-crops, fisheries, grazeland, domestic, construction, industrial), as well as for pre-agreed standards to be met by effluent discharges from industrial and agro-industrial processes.

In the urban context, migration to the cities in search of a better life has led to rapid urbanization, which has resulted in large overcrowded communities of urban poor people with limited access to education, jobs, water supplies, sanitation, energy and health services. These communities can also cause negative impacts on urban and peri-urban environments – e.g. along urban watercourses and forests, which, coupled with pollution of air, land and water from uncontrolled industrial discharges and local business activities, exemplify the environmental and socio-economic imbalances of a developing economy struggling to translate economic growth into socially equitable and environmentally sustainable development. In conclusion, both rural communities and the urban poor live with the threats from poverty, environmental degradation, pollution and climate change, and the poorest people are the most vulnerable.

Therefore, the nexuses between water, energy, food, land use, industrialization, urbanization and population highlight new tensions and point to the need for research, innovation and governance anchored in society's participation to co-design and manage natural resources sustainably in Ethiopia. Cooperation among stakeholders is core to the National Science, Technology and Innovation (STI) Policy of Ethiopia, and this and other policies and examples of how sustainability is understood in the country are examined in the following sections.

3.4. National strategies and policies addressing sustainability

This section explores to what degree pressing developmental and sustainability issues reflected in the United Nations Sustainable Development Goals (SDGs) such as 'ending poverty', 'ending hunger and improving food security and nutrition', 'achieving gender equality', 'ensuring health and promoting well-being for all', and 'ensuring access to water and sanitation for all', are embedded in Ethiopian policies and in the research and innovation priorities of governmental programmes. In order to do so, this section provides an overview of relevant policies in place in Ethiopia, which is followed by a summary of key findings from interviews, along with examples of how policies are being implemented 'on the ground'.

3.4.1. Sustainable development: National Report of Ethiopia

The three spheres of sustainable development were integrated in Ethiopia's research, policy and implementation initiatives by the Environment Protection Authority (currently the Ministry of Environment, Forest and Climate Change – MEFCC) via the *National Report of Ethiopia*, presented to the United Nations Conference on Sustainable Development (Rio+20) in 2012 (see EPA, 2012). Areas prioritized by the EPA representing Ethiopia's government position in the early 2010s include:

- Impacts and relationships between population growth and urbanization and environmental degradation;
- Expansion of agriculture to the detriment of forests;
- Energy access and links to deforestation;
- Water resource availability and sustainability (e.g. diminishing/deterioration of water resources);
- Water and sanitation in rural areas and for the urban poor;
- Links between deforestation and rainfall intensity and land degradation/soil erosion;
- Water-energy-food nexus (e.g. hydro, biofuels and biocrops);
- Agro-businesses, water resource management and pollution prevention;
- Industrialization, resource efficiency/resource recovery and pollution prevention; and
- Climate change mitigation and clean energy (including hydro and biofuels), climate change mitigation and carbon-neutral development, climate change impacts and adaptation (including water and agriculture sectors and socio-economic).

3.4.2. Growth and Transformation Plan (GTP)

The Growth and Transformation Plan (FDRE, 2011*b* and GTP, 2013) is a national five-year plan created by the Ethiopian Government to improve the country's economy by achieving a projected GDP growth of 11–15% per year from 2010 to 2015 (see FDRE, 2011*b*). The GTP builds on the Plan for Accelerated and Sustained Development to End Poverty strategies for 2005/06–2009/10 (PASDEP). The GTP aims 'to achieve the Millennium Development Goals (MDGs) in Ethiopia by 2015 and middle-income status for Ethiopia by 2020–23'. The GTP objectives are:

1. To attain high growth within a stable macroeconomic framework.
2. To achieve the MDGs in the social sector.
3. To establish a stable democratic and developmental state.

The GTP identifies 7 strategic pillars that will drive these objectives: 1) sustain rapid growth; 2) emphasize agriculture; 3) promote industrialization; 4) invest in infrastructure; 5) enhance social development; 6) strengthen governance; and 7) empower youth and women. According to the World Bank (2011): *'The GTP's objectives are in line with their strategy in Africa to promote employment, enhance governance and public sector capacity and reduce vulnerability'.*

3.4.3. Climate Resilient Green Economic (CRGE) plan

At the rate of economic growth that Ethiopia has experienced in recent years, the government of Ethiopia aims to achieve middle-income status for the country by 2025, but crucially the intention is to follow an unconventional development path to minimize GHG emissions and unsustainable use of natural resources. Thus, in order to avoid the negative effects for the environment and society that are linked to rapid economic growth, in 2011 the government of Ethiopia developed a Climate Resilient Green Economic (CRGE) plan which is in line with the GTP and aims for Ethiopia to follow a sustainable model of growth up to 2030. If Ethiopia were to achieve its ambition to be a middle-income country by 2025 following a conventional pathway, GHG emissions would more than double from 150MtCO2e today to 400MtCO2e in 2030 (see FDRE, 2011*a*). The CRGE strategy aims to maintain Ethiopia's low emissions trajectory and will require *'boosting agricultural productivity, strengthening the industrial base, and fostering export growth'*,[16] which will translate into a shift in GDP shares from the agriculture sector in favour of the industrial and service sectors. A key element of the CRGE plan is the promotion of carbon-neutral energy sources such as hydroelectricity, geothermal, biofuels, solar and wind power to drive clean industries and green economic development.

3.4.4. Climate Change National Adaptation Programme of Action (NAPA)

In 2007, the Ministry of Water Resources and the National Meteorological Agency produced a Climate Change National Adaptation Programme of Action (NAPA) for Ethiopia. This includes policies, strategies and a programme to enhance the adaptive capacity of Ethiopian people and reduce the vulnerability of the country to climate variability and change. The Plan for Accelerated and Sustainable Development to End Poverty (PASDEP) which was the precursor of the GTP described above, the Environmental Policy of Ethiopia, the Agriculture and Rural Development Policy and Strategy were all produced as part of the NAPA programme through stakeholder consultations and expert assessments on vulnerabilities in the country. Geographically, the most acute vulnerabilities were found in ecologically arid, semi-arid and dry subhumid parts of the country affected by droughts, while by sector, the agriculture sector was found to be most vulnerable to climatic variations. In terms of livelihoods, small-scale rain-fed subsistence farmers and pastoralists were identified as the most vulnerable (for NAPA report, see FDRE, 2007).

16 http://www.ethcrge.info/crge.php

3.4.5. Nationally determined contribution (NDC) of Ethiopia

Nationally determined contributions (NDCs) are at the heart of the Paris Climate Change Agreement of 2015 and signify the national efforts of each of the 196 signatory parties to achieve long-term sustainable development goals aiming at limiting global warming to 1.5–2 °C above pre-industrial levels[17] by reducing national GHG emissions and adapting to the impacts of climate change. Ahead of the Conference of the Parties (CoP) 21 in Paris in 2015, countries were asked to submit Intended Nationally Determined Contributions (INDCs) outlining targets for mitigation, and if possible for adaptation and financial commitments.

According to Ethiopia's INDC, published on 10 June 2015, the country intends to limit its net greenhouse gas emissions in 2030 to 145 Mt CO_2-e or lower. This would mean a reduction of 255 Mt CO_2-e from the projected 'business as usual' emissions for 2030, or a 64% reduction from the 'business as usual' scenario in 2030 (see FDRE, 2015). This includes 90 Mt CO_2-e from agriculture; 130 Mt CO_2-e from forestry; 20 Mt CO_2-e from industry; 10 Mt CO_2-e from transport; and 5 Mt CO_2-e from buildings.

3.4.6. Climate Change Education Strategy of Ethiopia (2017–2030)

In September 2017, Ethiopia launched its Climate Change Education Strategy and Priority Actions for the period 2017–2030. The strategy's vision is *'to see environmentally conscious citizens created at all levels of education with proper knowledge, skills and attitude that enhance our country's climate resilient and green economic development through climate change education'*. Thus, the strategy aims to integrate climate change education into the formal education system of Ethiopia by revising the curriculum, producing learning resources and training teachers. The Climate Change Education Strategy and Priority Actions are driven by the Ministry of Environment, Forests and Climate Change (MEFCC) and the Ministry of Education (MoE) of Ethiopia. These are in charge of implementing, monitoring and assessing the strategy and priority actions, and are supported by the United Nations Development Programme (UNDP) and the United Nations Institute for Training and Research (UNITAR), which since 2016 have consulted national stakeholders to ensure national ownership.

In parallel, and in order to raise awareness about climate change, Ethiopia – together with other African countries – has joined the UN Climate Change Learning Partnership (UN CC: Learn) programme run by UNITAR, which is a collaborative initiative launched in 2009 to support countries to design and implement systematic and results-oriented climate change learning, in order *'to unleash the untapped potential of the education sector towards realizing the country's widely shared aspiration of becoming a climate resilient green economy'*.[18]

3.4.7. Environmental Policy of Ethiopia

Ethiopia adopted and has been implementing its Environmental Policy since 1997. The overall policy goal is 'to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human and cultural resources to meet the needs of the present generation without compromising the ability of future generations to meet their own needs'.

The policy strives to ensure that essential ecological processes and life support systems are sustained, biological diversity is preserved, and renewable natural resources are used in such a way that their regenerative and productive capabilities are maintained, and where possible enhanced, so that the needs of future generations are not compromised. Where regenerative and productive capabilities are already impaired, the policy urges restoration of these capabilities through appropriate interventions (see FDRE, 1997).

3.4.8. Agriculture and rural development policies and strategies

In line with meeting Ethiopia's objective for economic development outlined in the GTP, the country's approach has been to accelerate economic growth to benefit the majority of the population and to improve the country's position in the global market economy, while moving away from the situation of the country being a food-aid recipient.

To achieve Ethiopia's economic development objective, the Government of Ethiopia has produced the Agriculture Development-led Industrialization (ADLI) policy which aims at transforming the country's economy via transforming its largest sector, the agriculture sector, which strongly influences the overall economic performance of Ethiopia. There have been achievements from the implementation of the ADLI policy since

17 https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs#eq-4

18 https://www.unitar.org/ethiopia-launches-implementation-its-national-climate-change-education-strategy-and-priority-actions and https://www.uncclearn.org/national-projects/un-cclearn-ethiopia

1991,[19] and a series of agriculture and rural development policies have been formulated, for example the agriculture-centred rural development programme, which is one of the major strategies at the core of the development plans of the nation and the basis for other efforts towards economic development (FDRE, 2003).

Also noticeable is the Ethiopian Strategic Investment Framework (ESIF) for Sustainable Land Management, which was developed by the Ministry of Agriculture and Rural Development's Soil and Land Management (SLM) Secretariat in 2008, in partnership with other key government offices and higher education institutions, NGOs and local communities. The secretariat prepared a long-term strategy and programme for sustainable land management to be implemented over a 15-year period, starting from 2009 (Forum for Environment, 2010).

3.4.9. Policy, strategy and proclamation on forest development, conservation and utilization

The basic aim of the policy is to meet public demand in forest products and foster the contribution of forests in enhancing the economy of the country through appropriately conserving and developing forest resources (Forest Development, Conservation and Utilization Proclamation No. 542/2007). The forest policy and strategy cover:

- Fostering private forest development and conservation;
- Expansion of forest development technology;
- Expanding market development for forests;
- Administration and management of state forests;
- Protecting forest resources from threats; and
- Establishing modern information systems on forest development, conservation and utilization.

3.4.10. Ethiopia's National Biodiversity Strategy and Action Plan 2015–2020

In 2005, Ethiopia prepared the first National Biodiversity Strategy and Action Plan (NBSAP), which was implemented in the period between 2005 and 2010. Following the termination of the first NBSAP, the country has prepared the strategy plan 2015–2020. The vision of the strategy is *'that by 2050, Ethiopia's biodiversity and ecosystems are conserved and sustainably utilized by all actors providing food security and contributing to poverty eradication and improved quality of life of the Ethiopian people'* (EBI, 2015).

3.4.11. Industrial Development Strategy

Ethiopia's government describes itself as 'developmental' and recognizes the need to support private sector development as having an important role in the economic growth and productivity enhancement of the nation, thus the government is committed to advancing industrialization and other private sector activities driven by the desire to lay the foundations for long-term economic development. Accordingly, the Industrial Development Strategy of 2002 mentions the importance of state leadership to challenge and support developmental firms, as well as emphasizing the importance of the private sector and the need to build on both foreign and domestic investors. Furthermore, it specifies priority areas for selective interventions that favour certain sectors over others (Altenburg, 2010).

3.4.12. Solid Waste Management Proclamation

The Solid Waste Management Proclamation was passed by the government in 2007, but it is still being implemented, and solid waste management is still a major challenge in most cities and urban centres. However, there are promising initiatives, such as the 'waste to energy' facility under construction in Addis Ababa, described in section 3.2.2, which will be replicated in other Ethiopian cities in the near future.

3.5. Ethiopia's national innovation system

3.5.1. Mission and structure

The historic background of the STI Policy of Ethiopia is described in detail by Weldegiorgis (2015). The first Science and Technology Policy (STP) of Ethiopia was created under the 'Derg' Marxist regime and was subsequently carried over by the transitional government as the 'Ethiopian Training and Education' policy of 1994, which gave priority to *'research of practical societal impact'*.

With the introduction of the GTP, the policy was revised and in 2010 became the Science, Technology and Innovation (STI) policy to accommodate changes in strategy in the country.

19 Ministry of Agriculture Ethiopia: http://www.moa.gov.et/en_GB/policies-and-strategies

The main objectives of Ethiopia's STI policy (FDRE, 2010) summarized by Weldegiorgis (2015) are:

1. To establish and implement a coordinated and integrated general governance framework for building STI capacity;
2. To establish and implement an appropriate national Technology Capability Accumulation and Transfer (TeCAT) system;
3. To promote research that is geared towards technology learning and adaptation;
4. To develop, promote and commercialize useful indigenous knowledge and technologies;
5. To define the national science and technology landscape and strengthen links among different actors in the national innovation system;
6. To ensure implementation of STI activities in coordination with other economic and social development programmes and plans; and
7. To create a conducive environment to strengthen the role of the private sector in technology transfer activities sustainably.

The organigram shown in **Figure 3.3** illustrates the national innovation system of Ethiopia following the SETI organizational structure developed by the UNESCO Global Observatory of STI (GO→SPIN) methodology for mapping research and innovation in various African nations (UNESCO, 2015). It shows the organization of responsibilities for planning and implementing a given policy, and distinguishes five levels:

a) Policy-planning level (policy design).
b) Promotional level (funding and coordination).
c) Performance level (execution of R&D and innovation).
d) Science and technology services.
e) Assessment/evaluation level.

The Office of the Prime Minister, working closely with the Ministry of Science and Technology and research institutes, constitutes the policy design – level (a) – in Ethiopia. At the funding level (b), overviewing and promoting research and innovation, driving implementation of the policies and channelling the finances are the line ministries. At the performance level (c), there are research institutions and universities (public and private), as well as institutions such as the Ethiopian Investment Commission and regulators such as the old Environment Protection Authority (currently the Ministry of Environment, Forest and Climate). Applied research institutes and universities are placed at the scientific and technological services level (d). The ministries, and ultimately the Office of the Prime Minister, are also in charge of the research assessment/evaluation (level (e)).

3.5.2. STI policy implementation in Ethiopia

A reference framework for implementation of STI systems has been defined in UNECA (2016), based on the work on STI policies and systems in African countries by Nwuke (2015). This was used for reference, together with the work by Weldegiorgis (2015), to discuss the implementation of the STI policy and activities in Ethiopia.

Based on the middle pathway for implementation of STI policy in education and regulation defined by Nwuke (2015), the review of Ethiopia's STI system by Weldegiorgis (2015) finds that in relation to innovation and research, the 1994 Training and Education Policy of Ethiopia proclaims that research of practical societal impact will be given priority. Therefore, 'applied research' (also described as exploitative research) receives the largest amount of funding (56% of the budget), compared to 'innovative' (also referred to as exploratory or experimental research) that receives 33% of the budget, and 'basic' research that receives 11% of the budget, based on data from 2014.

According to Weldegiorgis (2015), *'research focus in Ethiopia is generally leaning towards research with applied outcomes'*. This was corroborated by interviewees from the Ministry of Science and Technology (MoST) of Ethiopia, who stated that *'the government is the main funder of research and it is obliged to make sure that tax-payers' money is best channelled to address societal issues'* and that research has to *'contribute to the development agenda of the country'*. The same source, based on interviews also carried out among research officers in High Education Institutions (HEIs), confirmed that universities agree with the principle that research focus has to be on *'solving socio-economic problems'* and on *'improving the quality of life of people'*. However, all the interviewees agreed that, in addition to applied research, exploratory research is also needed in the long term, as the country's STI activities depend on technological innovations.

Weldegiorgis also reports that because little investment goes into explorative research and technological innovation, there is little or no investment in renewing equipment and research facilities, in investing in technically-skilled staff and qualified researchers, and in developing partnerships with industry and businesses in order to innovate.

Figure 3.3 illustrates Ethiopia's research and innovation structure focusing on policies and actors relevant to sustainability science.

Weldegiorgis refers to partnerships between government, universities and industry (public-private partnerships) as the 'Triple Helix' and stresses that the private sector involvement in STI activities is crucial, as it can strengthen the weak Triple Helix connection to assist STI policy implementation

Ethiopia national innovation system

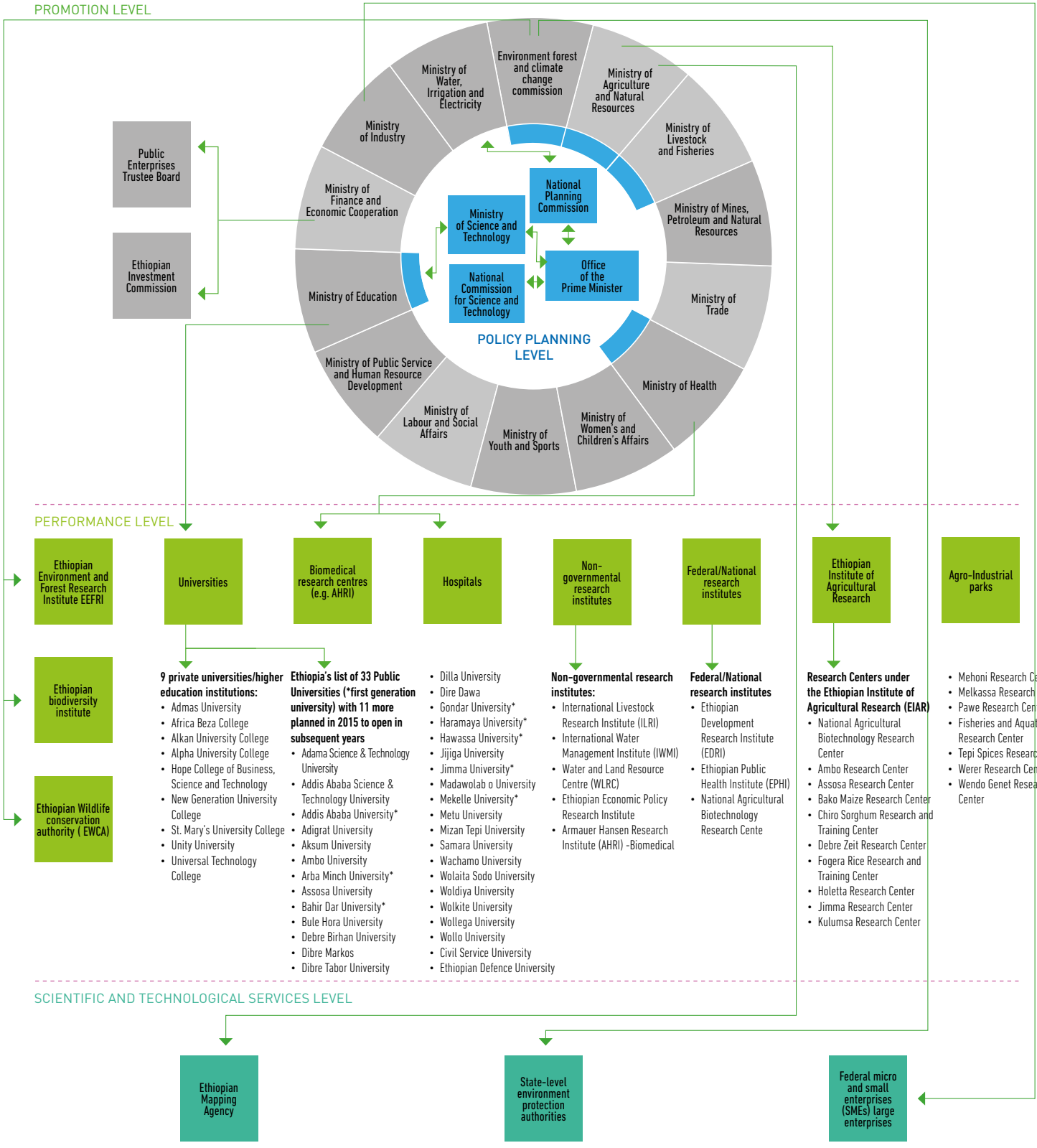

Figure 3.3. Organizational chart showing Ethiopia's research and innovation system.
Source: Authors' production based on GO→SPIN methodology (UNESCO, 2015)

and financing. The author calls for universities to go beyond training and educating students to work with government to establish industrial internships, incubation centres, science parks, affiliated enterprises and consultancies, and to raise awareness in the manufacturing sector and among micro and small enterprises (MSEs) about the benefits of STI. Incipient examples of this model of external funding, such as from European donors who collaborate with private businesses and university research students to do applied research in rural communities, can be seen under the Horn of Africa Regional Environment Centre and Network (HoAREC/N).

Some developments are reported in relation to partnerships, as Ethiopian universities have established Knowledge and Technology Transfer (KTT) offices to disseminate research outputs, and are signing Memorandums of Understanding (MoUs) with industry actors. However, Weldegiorgis (2015) reports that these are so far only agreements 'on paper' and that the involvement of industries and MSEs in research and in exploiting research and technology outputs is still very limited. A similar situation is reported for Central American countries, as described by Padilla and Gaudin (2013), indicating that translating STI policy into practice remains an important challenge for developing economies.

Weldegiorgis (2015) also points out that the lack of financial resources is the most significant barrier for effectively implementing the STI policy in Ethiopia, but that there are also problems due to the 'top-down' approach to policy formulation, limited public awareness of the significance of STI, and the few programmes that translate STI policy objectives into action.

On the other hand, an empirical study on green industrialization and innovation in Ethiopia's cement, leather and textile sectors suggests low rates of product and process innovations among large or medium-sized firms in Ethiopia. Based on the premise that innovation is a critical driver for industrialization, different actors, interactions and communication pathways were examined as part of this work, and relationships between enterprises, government offices and the training institutes of leather and textiles were mapped out. The project investigated whether there are various types of innovation by the enterprises; whether enterprises drive their own innovations or others do, and if there is an enabling environment; whether innovation is demand- or supply-driven; and if greening requirements in Ethiopia drive innovation at all, or whether it is financial drivers and/or the presence of new technologies in the market that encourage innovation.

Findings from the study are summarized by Wakeford *et al.* (2017) and the paper reports that the *'main inhibitors of innovation are high costs of technology, inadequate finance and limited information'*, while the main driver of firms' innovation is *'to improve competitiveness, while reducing environmental impacts and meeting environmental regulations were among the least important motivators'*. The study also found that interactions among firms, government and other actors encourage innovation, thus the authors recommend enhancing relationships among key actors, providing financial incentives for firms, and enforcing environmental regulations.

Also in relation to barriers, according to the International Organisation for Knowledge Economy and Enterprise Development (IKED), the World Economic Forum's rankings suggest that despite Ethiopia's efforts to improve its investment climate, the country's competitiveness level might be limited by weaknesses related to the innovation and technology system, such as *'the lack of appropriate innovation inputs, the quantity and quality of the entities that make up the innovation system, and finally and perhaps most importantly, the strength of the linkages within this system'* (IKED, 2006). According to this source, a measure of both innovation input and system linkages is the information and communications technology, which needs to improve in Ethiopia in order to promote innovation as part of the demand articulation process (see Smits, 2002; Boon et al., 2011).

3.6. Sustainability science in Ethiopia

There are some differences in how sustainability is understood or which elements of sustainable development are prioritized, depending on the sector and agents involved in a particular initiative. For example, for the Ethiopian Investment Commission, the economic investment of businesses and industries that help job creation may be prioritized over other social and environmental concerns of local communities of farmers and fishermen, at least in the first instance. On the other hand, these concerns may be given more weight by other ministries, government agencies and interest groups. This exemplifies the need for wide multistakeholder engagement to embed sustainability science principles towards trans- and interdisciplinary, co-produced and actionable knowledge in the national innovation system in Ethiopia.

How sustainability science is understood and embedded in Ethiopia's policies is further examined below via interviews with key actors, and case studies of applied research projects and implementation initiatives around broad sustainable development topics that have been recently funded in Ethiopia

(see **Table 3.1**). These illustrate how the sustainability science approach[20] is being integrated in science and innovation activities in the country in line with the priority areas listed above.

Furthermore, as mentioned in section 3.2.3, there is an urban-rural duality clearly differentiated in Ethiopia when exploring and addressing sustainability issues, with Addis Ababa (and increasingly other cities and peri-urban settings) showcasing the urban sustainable development issues faced by the country. This clear difference between rural and urban challenges and the prioritization of efforts is reflected in some of the projects and programmes described in **Table 3.1**, while multidisciplinary, action-oriented participatory research efforts are also illustrated via case studies in the following section.

The interviews and project examples presented here show practical ways to address sustainability challenges and balance economic, environmental and social priorities by building consensus on new strategies and solutions to sustain people, the planet and shared prosperity.

3.6.1. Interviews on the concept of sustainability and innovation

Semi-structured interviews were held in 2017 (López-Avilés, 2019) with academics and researchers selected on the basis of their involvement in green innovation and sustainability in the industrial and agro-industrial sectors of Ethiopia via two projects: *Interactions of industrial policy and green economy in Ethiopia* and *Agro-industries and Clean Energy in Africa (AGRICEN)* undertaken between 2013 and 2018 under the direction of Prof. Y. Mulugetta (see Wakeford et al., 2017).

Below is a summary from the interviews held with Dr Kassahun Yimer Kebede from the School of Mechanical and Industrial Engineering at Addis Ababa University, Dr Mulu Gebreeyesus from the Ethiopian Development Research Institute (EDRI) and Professor Yacob Mulugetta from University College London, as well as with Ms. Yeshi Chiche, previously employed at the Ethiopian Agricultural Research Institute (EIAR) and an attendee at workshops organized by UNESCO and the Ethiopian Environment and Forestry Research Institute (EEFRI) as part of the Future Earth project activities in Ethiopia, who shared her experience in relation to the role of women in science, and specifically in the forestry sector, in Ethiopia.

The concept of sustainability

Regarding the concept of sustainability, Dr Kassahun indicated that the terminology is relatively new in discussions about sustainable engineering at the faculty level; it is seen mainly in relation to green industrialization, green manufacturing, and green engineering and energy/energy systems. In engineering, sustainability is seen as synonymous with green, and thus it refers to reductions in greenhouse gas emissions (carbon footprinting) and pollution, as well as efficient resource utilization. It also refers to resource-sensitive designs for the efficient utilization of scarce resources and the impacts on the environment.

For development economists such as Dr Mulu Gebreeyesus from EDRI, the concept of sustainability also resonates with green industrialization, and 'green' innovations to improve resource productivity and reduce pollution. He has applied sustainability science concepts in his work on innovation systems analysis and the development of industries nationally, via a project led by Prof. Yacob Mulugetta of University College London, which considered the leather, textile, garments and cement industries, including both environmental and also socio-economic aspects. Conclusions from this study are reported by Wakeford et al. (2017); at the interview, Dr Gebreeyesus reiterated that implementation and enforcement of environmental regulations is still weak in Ethiopia and has not led to innovation so far.

To use the example of regulation around effluent discharges, regulators such as the Ministry of Environment, Forest and Climate Change (old national federal Environment Protection Authority – EPA), Addis Ababa's EPA and Addis Ababa Administration are in agreement on the policy and regulatory aspects about effluent discharge, but the additional cost of implementing measures to clean effluent and to enforce environmental regulations means that these are the weakest links.

However, some positive examples, such as the recent intervention by the Ethiopian Government to close six tanneries located near Addis Ababa in Gulele and Akaki-Kaliti (see case studies), is evidence of environmental sustainability increasingly being taken more seriously in Ethiopia. The six tanneries reopened after a few days but the closures were a warning that they have to clean up their effluent discharges, and if problems are not remediated, they will be closed in six months.

In the same positive vein, there was a recent state-led intervention to drive the development of sustainable industrial parks, such as the pilot park of Hawassa for textiles and garments manufacturing, and the planned park of Modjo focused on the leather sector production and trade. This positive intervention aims at promoting the use of best practices and technologies to manage resources and to treat effluent efficiently

20 See http://www.scfoundation.org for sustainability science

via common, cost-effective facilities that serve several industries on the same site. This intervention has been designed to attract private investment, and to facilitate companies' compliance with existing environmental regulations on water quality standards.

There are also plans for integrated agro-industrial parks (IAIP) and plans for parks/clusters of small and medium enterprises (SMEs). The IAIPs will be linked to rural transformation centres where harvests will be processed, and the IAIPs will also be centres for production and training, storage, marketing etc. for the agriculture sector, which remains the biggest sector in Ethiopia's economy.

Indigenous and local knowledge

Regarding the contribution of indigenous and local knowledge for sustainability, Dr Kassahun stated that the industrial engineering curriculum is based on Western engineering education and technology, but he recognized that there are numerous initiatives in manufacturing that are bottom-up or 'informal', and often based on indigenous and local knowledge, e.g. the processing and marketing of traditional medicinal plants, such as shea butter and moringa, for healing and cosmetic uses.

In terms of grassroots or social innovations, Dr Gebreeyesus pointed to innovative elements in the textiles and metal sectors. Examples of innovation for sustainability in small businesses include shoes manufacturers that use recycled and local materials (e.g. car tyres) and a local workforce. There are also examples of textile and garment businesses that produce high-quality traditional cotton clothes and embroideries and transform them into Western-style garments and other items, such as towels and tablecloths for the national urban and international markets. Some of these are started as charities with international and national donor capital, for example women affected by/widows of HIV producing bed covers. Others are private enterprises, some of which have foreign or diaspora financing (e.g. shoes, tablecloths and scarves - see photos 3.4 and 3.5). However, there is the risk of losing this type of local innovation as these communities of entrepreneurs are becoming dispersed from places such as the market 'Merkato' in Addis Ababa (see Gebreeyesus and Mohnen, 2013). The same can be said about the risk of losing indigenous knowledge, for example among the Southern Peoples and Gambella pastoralist communities, whose nomadic traditional way of life is under pressure due to land-use changes and the regulation of river flows via dams for hydroelectricity and irrigation.

Gender and science

Regarding gender and science, Ms. Yeshi Chiche stated that based on her experience, female participation in science appears lower in Ethiopia compared with other African countries that she has visited for work and where she has colleagues. For example, the forestry sector in Ethiopia is mainly male-dominated, with female participation in professional forestry activities standing at less than 10%. At the Ethiopian Environment and Forestry Research Institute (EEFRI), there are 23 researchers with a Ph.D. qualification, and only one of those is female. In agreement with these reflections, **Figure 3.4** illustrates the proportion of female researchers by sub-Saharan African country. Ethiopia is one of the countries with fewer female researchers, ranking second from the bottom, although data was not available from all countries.

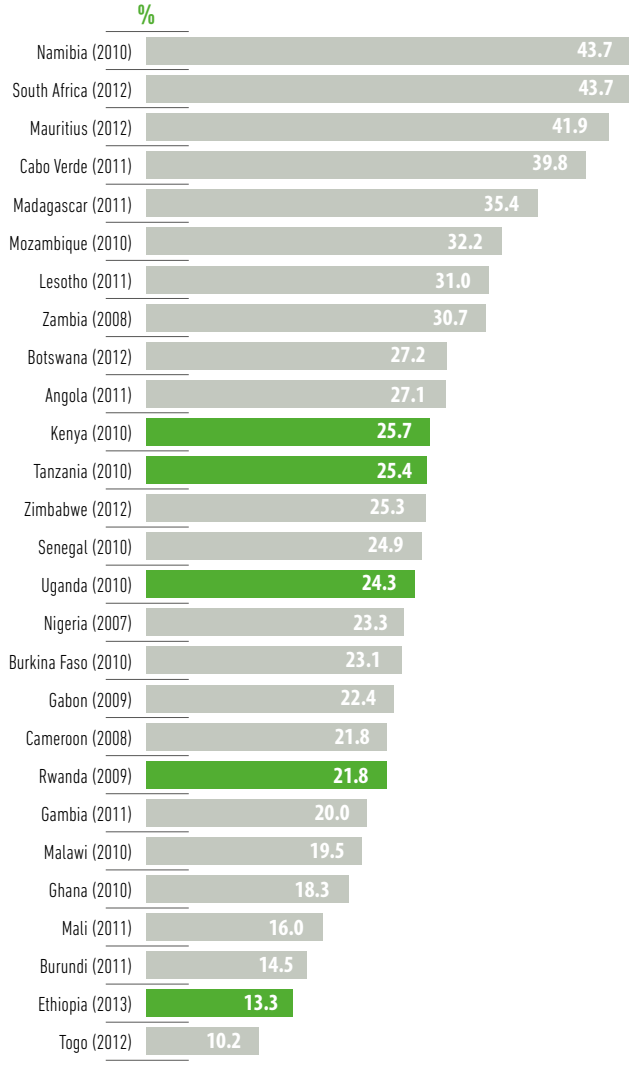

Figure 3.4. Percentage of female researchers in sub-Saharan Africa.
Source: UNESCO, 2015.

The reasons behind the poor representation of women in science in general – and forestry specifically – may be cultural, given that these fields may be viewed as 'male' subjects. Also, at the grassroots level, especially in rural areas, girls have

fewer opportunities to attend school in the first place, and they leave school earlier than boys due to pressures to look after the household and family members, to marry, or to work and contribute economically to impoverished households (see photos 3.6 and 3.7). The interviewee indicated that there is a need for more capacity-building, as well as education and job opportunities for women at all levels.

On the subject of opportunities for women, some hopeful signs are seen in education, with initiatives such as entrance quotas giving priority to women applying to Ethiopian universities.

Having said that, university students represent a very small fraction of all women and girls in the country, and gender inequalities are complex and linked to cultural, economic, religious and moral values in all regions in Ethiopia. Over 14 years of age, more boys than girls remain in education, as seen in previous sections. There is also a clear difference between the urban and rural environments, and the economic situation of families, with approximately three times more rural and poorer children below the age of 14 years out of school, and nearly twice as many out of school for the group of children above 14 years of age. In the rural environment, religious, cultural and family pressures in predominantly patriarchal and authoritative societies can inflict powerful – if silent – pressure on girls and young women to take on the role of helpers, housekeepers and wives from an early age, thus abandoning school and any opportunity to get a formal education and a paid job.

3.6.2. Examples of projects and programmes on sustainability science

To complete the overview from interviewees on the implementation of the sustainability science approach in Ethiopia, a number of concrete projects and programmes are presented in **Table 3.1**, which includes key words to describe the type of projects carried out, their innovative aspects, the funders and partners, and links to websites.

Table 3.1. Examples of sustainability science research projects and programmes in Ethiopia

Programme/project title, funders and partners	Key words and links to website
UN CC: Learn in Ethiopia *United Nations Development Programme (UNDP) and United Nations Institute for Training and Research (UNITAR), Ministry of Environment, Forest and Climate Change (MEFCC) and the Ministry of Education (MoE)*	Climate change, education https://www.uncclearn.org/national-projects/un-cclearn-ethiopia
Agro-industries and Clean Energy in Africa (AGRICEN) *EPSRC, DFID, DECC, University College London and other UK Universities, Ethiopian government/ministries/ businesses, plus other African partners*	Political economy, agro-industries, clean energy http://www.ucl.ac.uk/steapp/research/projects/agricen
Aligning industrial polices and green economy strategies in Ethiopia *CDKN, Ethiopian government/ministries/businesses*	Industrial policies, green economy strategies, innovation, large and medium-sized firms https://cdkn.org/project/industrial-polices-and-green-economy-strategies-ethiopia/?loclang=en_gb
BioInnovate programme: 'Development of efficient technologies for the sustainable treatment of high strength wastewater in the Modjo River' project *Swedish Development Agency (Sida), Addis Ababa University, Ethiopian leather businesses, Addis Ababa Administration*	Integrated agro-industrial wastewater treatment, value-added innovations, biogas, water and nutrient recycling, tanneries (see Case Study 1) https://bioinnovate-africa.org/bio-innovate-developing-innovations-for-integrating-waste-management-and-bioenergy-production-in-ethiopias-tannery-industry/
Capacity development for the preparation of Ethiopia's Master Land-use Plan *Food and Agriculture Organisation of the United Nations (Ethiopia)*	Forest inventory, baselines, monitoring, reporting, verification http://www.fao.org/technical-cooperation-programme/en/ http://coin.fao.org/coin-static/cms/media/18/13770899903620/adama_inception_workshop.pdf
Scaling up Participatory Forest Management (PFM) project *European Union /Ministry of Agriculture (MoA)*	Forest improvements, forest-based livelihoods, capacity-building, local communities, mainstream, scale-up https://theredddesk.org/countries/initiatives/scaling-participatory-forest-management-project
Institutional strengthening for forest sector development in Ethiopia *UNDP and Norway, the Government of Ethiopia*	Forest coverage, carbon sequestration, environmental services, sustainable supply of wood and wood products, capacity-building, stakeholder engagement, forest conservation, private sector, policies, interventions, innovation http://www.et.undp.org/content/ethiopia/en/home/operations/projects/climateriskandresilience/project_institutionalstrengtheningfoforestsectordevinethiopia.html

Programme/project title, funders and partners	Key words and links to website
Strategic Climate Institutions Programme (SCIP): Akaki *DFID UK-Aid, the Royal Norwegian Embassy, the Royal Danish Embassy*	Stakeholders, government, civil society, private sector, research organizations, climate resilient green economy, transition, participatory monitoring, evaluation, green enterprises unemployed youth, single parent families, women https://home.kpmg.com/ke/en/home/services/advisory/international-development-advisory-services/our-sectors-idas/react-and-resilience-sector/strategic-climate-institutions.html http://phe-ethiopia.org/admin/uploads/attachment-2217-SCIP%20Update%20(September%202015).pdf
African Adaptation Programme (AAP) in Ethiopia *Government of Japan, UNDP, UNICEF, federal EPA (currently Ministry of Environment, Forest and Climate), regional/local authorities and communities*	Multiple stakeholders, engagement, businesses, local and regional governments, local communities, innovation, land and ecosystems restoration, erosion and flood mitigation, afforestation, biofuels, livelihoods diversification, sustainable fisheries (see Case Study 2) www.et.undp.org/content/ethiopia/en/home/operations/projects/climateriskandresilience/project_AAP
Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia (2007) *Ministry of Water Resources and the National Meteorological Agency*	Adaptive capacity, reduce vulnerability, climate change, financial and technological support, stakeholder consultation, agriculture, arid, semi-arid and dry sub-humid, drought, small-scale rain-fed subsistence farming, pastoralists, livelihoods https://unfccc.int/resource/docs/napa/eth01.pdf http://adaptation-undp.org/projects/ethiopia-national-programme-action-napa
Piloting community-driven climate-resilience building *Christian Aid Ethiopia (CA-E), Assosa Environmental Protection Association, Education for Development Association in Benishangul Gumuz (Sedal Woreda)*	Community-driven, climate-resilience building https://www.christianaid.org.uk/about-us/programmes/braced
Climate Change Knowledge Enhancement project *Inter-church organization for development cooperation (ICCO)*	Climate change information, communities, reduce vulnerability, climate change impacts, adaptation https://www.icco-cooperation.org/en/projects/stars
ROSA (resource-oriented sanitation) *European Union, Arba Minch Town Water Supply and Sewerage Enterprise, Arba Minch University, Idget construction SME, University of Natural Resources and Life Sciences, Vienna, Austria*	Sustainable sanitation, fertilizers, vegetables and trees https://www.sswm.info/sites/default/files/reference_attachments/ROSA%202006%20Arba%20Minch%20town%20ROSA%20project.pdf https://www.susana.org/en/knowledge-hub/resources-and-publications/library/details/1189
CLARA project in East Africa *European Union, Arba Minch Town Water Supply and Sewerage Enterprise, Arba Minch University, University of Natural Resources and Life Sciences, Vienna, Austria*	Capacity, water supply and sanitation, peri-urban, rural, planning tool https://www.sswm.info/planning-and-programming/decision-making/situation-and-problem-analysis/clara-simplified-planning-tool https://forum.susana.org/forum/categories/164-financing-taxes-tariffs-transfers/7485-clara-simplified-planning-tool-to-compare-the-real-costs-of-various-alternatives-of-water-supply-and-sanitation-systems-in-the-pre-planning-stage#7485
Environmental uses of zeolites in Ethiopia *The Spanish Research Council CSIC, the Spanish State Research Agency (AEI) and the European Regional Development Fund Projects MAT2016-77496-Rand MAT2015-65767-P; Addis Ababa University*	Chemistry research into the potential of zeolites for removal of fluoride from drinking waters and chromium from tannery wastewater via the preparation of synthetic zeolites (see Diaz-Carretero, 2017) www.elsevier.com
Horn of Africa Regional Environmental Centre and Network's (HoARECN) programmes and projects:	
• **STRONGBOW** (Sustainable Tourism based On Natural resource management with Gender Balance towards Women)	Capacity-building, gender equality, eco-tourism
• **Sustainable development of the Gambella and Rift Valley landscape**	Conservation, ecosystem adaptation, landscape, governance, education, sustainable development, renewable energy, ecosystem-compatible agriculture, livelihood development
• **The Horn Re-Greening Programme**	Conservation and management of forests, rangelands and other ecosystems, biodiversity, rehabilitation of degraded areas, livelihoods
• **The Water Allocation Plan Development Project**	Water availability, utilization and allocation, sustainable water governance, mediation, conflicting interests, water uses
• **The Environmental Service and Climate Change Analyses Programme (ESACCAP)**	Adaptive capacity, vulnerability, climate change, shocks, impacts, agricultural and pastoralist communities, food insecurity, ecosystem degradation
• **The Climate Change Programme, the Sustainable Energy Programme and the Clean Energy Access Programme in Ethiopia**	Sustainable, local, fuel alternatives, renewable sources, waste-to-energy, bio-gas, briquette burning and efficient cooking stoves, affordable solar lighting http://hoarec.org/

Source: Original list, compiled in 2017, by the authors of this chapter.

Photos 3.4 and 3.5. Eco-tourism is becoming an additional source of income for local communities involving adults as well as children in various activities across the country. Photo 3.4 shows a good example of eco-innovation and indigenous sustainable practices where local plant resources are used as natural dyes to produce colourful scarves made with locally grown cotton for sale to tourists in Bahir Dar, northern Ethiopia. Photo 3.5 shows a boy using the decorated family's horse to offer rides to hikers in Wenchi Crater lake in western Ethiopia.

3.7. Co-designing science and innovation in Ethiopia

The case studies presented below represent successful examples of sustainability science and innovation practices, engaging multiple stakeholders and disciplines for more sustainable leather manufacturing, as well as forest, land and water management practices. Examples of livelihood improvement and promotion of ecosystem services via land restoration and afforestation, environmental education, community-based biogas and biofuel production, ecosystem rehabilitation and sustainable fisheries have been reported for projects undertaken in the Tekeze reservoir, Mount Guna, Debre Markos schools, Myliham, Bati and Lake Logo (see López-Avilés et al., 2013). The two examples presented here illustrate how stakeholders – including local communities with indigenous knowledge – worked with research institutions, practitioners, donors and government departments to co-generate innovative sustainable solutions.

3.7.1. Case study 1: Tannery waste into biogas and reusable water

By Seyoum Leta

Background and rationale

At present, the sustainability of water resources and socio-economic development in Ethiopia are threatened as a result of water overconsumption, pollution from industries and other anthropogenic activities, and climate change. Policy- and decision-makers face the dilemma of balancing products and job creation linked to industries such as the leather sector, and mitigating the health risks and environmental impacts posed by industrial effluents that impact on downstream users. Thus, innovative approaches to reduce pollution, recover and re-use resources offer solutions that benefit all stakeholders. Untreated or partially treated industrial discharges affect the health of local people and the environment, especially when industries are concentrated in clusters, such as is the case along the Modjo River, south of Addis Ababa in central Ethiopia. However, if properly managed, noxious effluent discharges can be a source of renewable energy and organic fertilizers, while environmental and health impacts can be minimized for downstream fishing, vegetable-farming and cattle-raising communities.

Objectives

- Develop technology to treat tannery wastewater, generate biogas from waste and recover resources such as chromium from the Modjo Tannery Ltd.
- Implement the technology via pilot plants.
- Ascertain opportunities for upscaling at Modjo Tannery and elsewhere.

Major achievements of the project

- Pilot facilities for bioenergy generation (biogas deposits, biodigesters) were constructed on-site.

- A wetland was constructed to treat wastewater, remove residual nutrients and other organic matter, and to trap heavy metals.
- 99% of the residual heavy metals and organic matter in the wastewater are removed.
- The tannery is able to treat about 10% of the waste to produce 60m^3/day of biogas.
- Biogas is used for cooking services and for an electricity generator for lighting at the Modjo factory.
- The annual energy expenditure of the tannery is offset by the biogas generated on-site.
- There is potential for upscaling to produce more biogas at the plant, which would more than double the factory's current energy costs, thus leading to further savings.
- Biogas generation on-site helps to reduce the rate of local deforestation for firewood and charcoal, as well as indoor air pollution and respiratory diseases, by eliminating smoke emissions.
- Treated effluent is reused in the factory's cleaning processes.
- Leftover effluent within national effluent discharge standards is released into the Modjo River.
- The reduced pollution burden benefits downstream communities that use water from the Modjo River for irrigation and drinking.

Best practice

The public-private sector partnership created between Addis Ababa University and Modjo Tannery Ltd. is a model replicable elsewhere. The technology is also transferable to other locations and industry types. For further information, see: https://bioinnovate-africa.org/bio-innovate-developing-innovations-for-integrating-waste-management-and-bioenergy-production-in-ethiopias-tannery-industry/

3.7.2. Case study 2: The Kebena river restoration project

By Alma López-Avilés, Samuel Tessema and Adugna Feyissa

Background and rationale

The Kebena is one of the four rivers flowing through Ethiopia's capital Addis Ababa as part of the Akaki river catchment. It crosses four sub-cities, flowing southwards from its source at the foot of Mount Entoto, covering key spots in the city. Like most rivers in the city, the Kebena is highly polluted. Untreated liquid effluent, human waste and solid waste are frequently disposed into its water. The stagnant water and foul smell are indicators of contamination which suggests the river can be a breeding ground for disease. Thus, the river is hazardous to the health of the community living along its banks and to people using its water for different purposes. Also, the effects of encroachment and inappropriate development linked to the massive urbanization of Addis Ababa, together with intense rainfall and deforestation in the upper catchment, are having impacts on the erosive capacity of the river and the frequency of floods. The river often breaks its banks during floods in the rainy season, causing damage to infrastructure and livelihoods along its course, and inhabitants who have accidentally fallen into it during past flood events have drowned. Climate change impacts such as increased rainfall intensity and changes in seasonality can lead to more frequent floods and droughts, which are expected to worsen the situation for the communities living along the river.

Decreasing the pollution levels of the river and taking steps to mitigate waste disposal and minimize the damage of floods and bank erosion are crucial for the local water environment and human population. Activities under this project included soil and water conservation measures, solid waste management, afforestation on riparian zones and biodiversity conservation, aiming at improving the quality of the environment and the lives of local residents by creating opportunities for additional income generation in the community.

Objectives

- Rehabilitate the riparian zones of the Kebena river, decrease pollution and eliminate waste disposal into the river, thus improving the quality of its water.
- Restore the natural environment on the banks by employing different conservation methods such as floodwater attenuation and storage, afforestation, water purification and development of fisheries.
- Improve the livelihoods of local communities by creating recreational and income-generating opportunities.

Major activities and achievements of the project

- Raising awareness about degradation and pollution levels of the river, and mitigation measures.
- Strengthening local institutions and creating associations, e.g. youth to engage in rehabilitation activities.
- Construction of a retention wall and gabion structure for soil and water conservation.

- Planting of indigenous trees, including fruits with nutritional value in riparian zones.
- Increased recreational value for local communities.
- Constructing filtering ponds, in order to use the river water for fisheries development.

Best practice

The project engaged local communities in the rehabilitation and sustainable preservation of the resources in and around the Kebena river. It also provided additional income opportunities, enabling local communities to become more resilient to the impacts of climate change.

For further information, see López-Avilés et al., (2013) and www.et.undp.org/content/ethiopia/en/home/operations/projects/climateriskandresilience/project_AAP

3.8. Conclusions and recommendations

The Ethiopian socio-economic, environmental and STI policy contexts have been presented in this chapter, together with examples of sustainable development programmes and projects that have successfully implemented multidisciplinary and participatory approaches for innovation and sustainability. Areas of improvement and strategies to facilitate interdisciplinary and inclusive research and innovation have also been discussed in previous sections. The findings of this review were complemented by feedback from stakeholders collected via two workshops held in Addis Ababa in February and November of 2017, which were organized by UNESCO and the Ethiopian Environment and Forestry Research Institute (EEFRI) – a focal institution in the Future Earth project activities in Ethiopia.

Photos 3.6 and 3.7. The female members of the family (including girls) are the main carers of children, the sick and elderly in both rural and urban Ethiopia, as illustrated in Photo 3.6 of a girl carrying her brother in central-western Ethiopia. Water and wood are also mainly collected by women and girls in Ethiopian households as seen in Photo 3.7 of a girl carrying a water jerry-can, also in central-western Ethiopia. These gender-determined chores often prevent women and girls from engaging in education and other economic activities compared to their male counterparts.

The conclusions from the review and consultation activities carried out to address core questions to advance sustainability science in Ethiopia are detailed below, together with some of the main recommendations.

3.8.1. Conclusions

Based on the review of sustainability and STI policies and their implementation seen above, some core scientific questions can be outlined which, if addressed, could help to strengthen sustainability science, technology and innovation in Ethiopia. For example, the work by Weldegiorgis (2015) identifies that 'explorative research' is understood as the only type of research 'capable of leading to innovation', while 'exploitative' or 'applied research' is perceived by Ethiopian Higher Education Institutions (HEI) actors as 'incapable of delivering innovation via practice'.

However, applied projects can be the cradle for innovation and co-generation of ideas combining Western science and indigenous knowledge. They can also initiate the collection of useful datasets for use in further research. Thus, accepting applied exploitative projects as 'innovative research' that can offer new or refined approaches to resolve sustainability problems is key. A change in what is conceived as 'research' by HEI and other Ethiopian actors may help to bring businesses, industries and society to work with academia to co-generate ideas and drive innovation for sustainability via applied projects.

In terms of sustainability science, two issues stand out that need to be addressed:

1. Defining suitable processes and parameters to measure sustainability; and
2. Obtaining and accessing sufficient data, especially for the physical environment.

These are challenges that hinder the advancement of sustainable development science, technology and innovation in Ethiopia. A reference framework of parameters and types of data that may be used to measure physical environmental sustainability aspects was created by Rockström et al. (2009), defining 'Planetary Boundaries'. This framework is based on nine Earth-system processes and associated parameters, as well as measured and proposed 'safe' thresholds or boundaries that should not be transgressed. The principle behind the Planetary Boundaries framework is that staying within the proposed safe boundaries will prevent human activities from causing unacceptable environmental change. Increasingly, an array of global tools and free databases may be used when applying Rockström's Planetary Boundaries framework to ascertain sustainability.

Core scientific questions that need to be addressed are access and availability of national and regional data due to fragmentation, unsystematic data collection and lack of open access, e.g. socio-economic data, such as health statistics, demographics, employment and investment figures, are collected in Ethiopia under different ministries, as well as by some multilateral organizations such as WHO, UNICEF, ILO and UNEP. In addition to data collected by these organizations, there is also a wealth of data collected unsystematically at grassroots level by the NGO sector and research students, also working in rural communities with women and children, pastoralists and the urban poor.

Finally, an agreed method to measure sustainability, linking environmental, social and economic spheres, is needed to analyse nexuses such as population growth, urbanization and environmental pollution; population, youth employment, industrialization, urbanization and detrimental impacts on water resources; population, deforestation and climate change; energy access, deforestation and land degradation; water resource availability, land use (e.g. bioenergy and cash-crops) and job creation, etc.

Conflicts over resource use (e.g. water, land, biomass) require that all stakeholders (policy-makers, regulators, water utilities and/or energy suppliers, farmers, fishermen, pastoralists, industries, businesses and other community users) participate in co-defining the method to measure sustainability and to govern equitably the natural resources, starting by determining the baseline situation and boundaries for sustainability, focusing on land/agriculture, water and the forestry/energy sectors. A better understanding of the environmental limits and the socio-economic context determining conflicts and demands on natural resources will allow stakeholders to formulate options and make informed decisions.

3.8.2. Recommendations for action

- Universities have a key role to play in capacity-building, knowledge and technology transfer, and co-designing research that could help the country to face sustainability challenges. However, in order to mainstream knowledge and promote research and innovation, more collaboration between academia, government and industry is needed as the private sector can be key in driving innovation and financing research (see Case Study 1 above).
- The primary focus of universities is on teaching activities and research budget allocations are small, thus links with industry, business and local communities should be promoted,

for example via 'incubator centres', developing ecosystem services and designing resource recovery schemes that could provide financial incentives for all partners.

- Funding for research and development can be helped by promoting a culture of multidisciplinarity and collaboration between administrations, donors and the private sector.
- In relation to the involvement of the private sector, the role of investors and businesses should be incentivized via regulation (e.g. tax breaks); STI policy should be mainstreamed to build social capacity towards sustainability; and environmental regulation should be enforced.
- Applied exploitative research, which is generally more attractive to the private sector, should be embraced by HEIs, and examples of successful applied research projects, as well as data collected, should be systematically recorded and made available for open use in knowledge transfer and for co-evolution of innovation.
- A number of development initiatives focused on sustainability science are presented in this chapter, as well as detailed examples of successfully implemented participatory projects that include traditional and local knowledge. Based on the existing understanding of sustainability science in Ethiopia, a framework is presented as a possible starting point to determine the baseline situation and boundaries for environmental sustainability in the country, focusing on land/agriculture, water and the forestry sectors. To balance environmental, social and economic dimensions, it is recommended that all actors have a better understanding of the environmental limits, as well as the socio-economic context. This will enable a comprehensive analysis of the sustainability nexuses and of specific conflicts around natural resource use, which in turn will facilitate stakeholder participation in formulating well-informed decisions.
- Indigenous peoples and knowledge are key to preserving and managing natural resources and should therefore be involved in the decision-making process and the co-design of research and innovation initiatives.
- Gender inequality is present at all levels in Ethiopia, with females under-represented in schools and universities, in projects, in leadership roles, and also in STI activities, which are significantly low compared to other countries in the Africa region. It is recommended that university degree quotas and gender-sensitive policy instruments may need to be relaxed to encourage more female students and ensure their research careers.
- For female students, and in general, more opportunities for postgraduate research should be created in the country, possibly in partnership with the private sector. Examples of such partnerships, as well as of technical cooperation and exchanges across universities and research institutions, should be facilitated and made public to encourage further links.
- Capacity should also be built in the private and government sectors to organize the youth and women into innovation- and services-related centres, for instance in biotechnology, clonal forestry and environmental management, so that the challenges of unemployment can be lessened.
- Specific areas for higher education and professional capacity-building in sustainability science outlined by STI stakeholders include: agricultural mechanization; biotechnology; climate information; stakeholder mapping and analysis; environment, e.g. ecosystem functioning, sustainable human living, sustainable resource management and forestry; writing and communication; information and communication technology; and project management (planning to implementation). The need for skills in integrated and multidisciplinary research, data collecting and monitoring, and for better laboratory infrastructure, were also highlighted by STI stakeholders.

Photo 3.8. Boys in rural areas are also engaged in household chores from an early age mainly helping to look after the family's livestock throughout the country, often while playing and sometimes attending school for a few hours per day. Photo taken in July 2013 in the outskirts north of Addis Ababa city.
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ETHIOPIA
East Africa

OVERALL PERFORMANCE

Index score

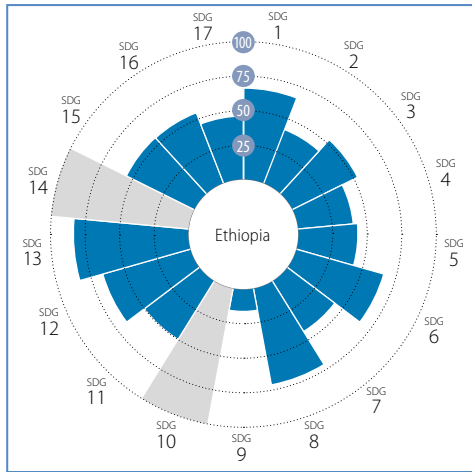
51.8

Regional average score

50.1

Africa Index Rank

23 (OF 51)



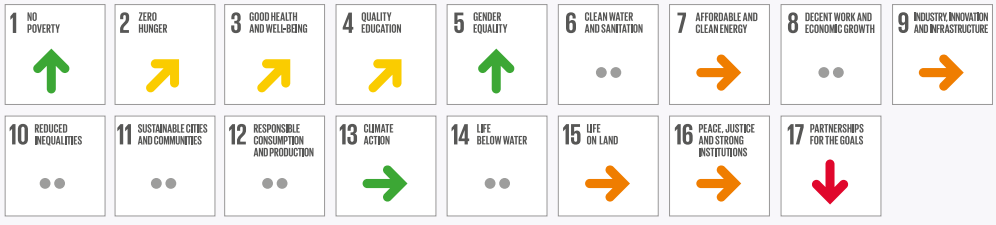
AVERAGE PERFORMANCE BY SDG

COMPARISON WITH OTHER AFRICAN INDICES

	RANK	SCORE
Africa Gender Equality Index (2015)	31 (of 52)	51.0 / 100
Africa Infrastructure Development Index (2016)	48 (of 54)	9.7 / 100
Africa Regional Integration Index (2016)	39 (of 52)	0.41 / 1
Ibrahim Index on African Governance (2017)	36 (of 54)	47.7 / 100

CURRENT ASSESSMENT – SDG DASHBOARD

SDG TRENDS



Notes: The full title of Goal 2 "Zero Hunger" is "End hunger, achieve food security and improved nutrition and promote sustainable agriculture".
The full title of each SDG is available here: https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals

Figure 3.5. Ethiopia Country Profile 2018.
The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

ETHIOPIA
Performance by Indicator

SDG1 – End Poverty	Value	Rating	Trend
Poverty headcount ratio at $1.90/day (% population)	16.4	●	↑
Projected poverty headcount ratio at $1.90/day in 2030 (% population)	1.6	●	••
Proportion of population living below the national poverty line	29.6	●	••
Population covered by Social Protection (%)	16.2	●	••
SDG2 – Zero Hunger			
Prevalence of undernourishment (% population)	28.8	●	••
Prevalence of stunting (low height-for-age) in children under 5 years of age (%)	40.4	●	→
Prevalence of wasting in children under 5 years of age (%)	8.7	●	→
Prevalence of obesity, BMI ≥ 30 (% adult population)	4.5	●	→
Cereal yield (t/ha)	2.5	●	↑
Fertilizer consumption (kg per hectare of arable land)	18.5	●	↓
SDG3 – Good Health and Well-Being			
Maternal mortality rate (per 100,000 live births)	353.0	●	↑
Births attended by skilled health personnel (%)	27.7	●	••
Neonatal mortality rate (per 1,000 live births)	27.6	●	↑
Mortality rate, under-5 (per 1,000 live births)	58.4	●	↑
HIV prevalence (per 1,000)	0.4	●	↓
People living with HIV receiving antiretroviral therapy (%)	59.0	●	••
Incidence of tuberculosis (per 100,000 people)	177.0	●	↑
Proportion of children under 5 with fever who are treated with appropriate anti-malarial drugs (%)	26.3	●	••
Malaria mortality rate	4.9	●	↑
Coverage of Preventive Chemotherapy for Neglected Tropical Diseases (%)	63.6	●	••
Age-standardised death rate due to cardiovascular disease, cancer, diabetes, and chronic respiratory disease in populations age 30–70 years (per 100,000 population)	19.3	●	→
Traffic deaths rate (per 100,000 people)	27.3	●	↓
Adolescent fertility rate (births per 1,000 women ages 15-19)	64.9	●	↗
Universal Health Coverage Tracer Index (0-100)	41.1	●	→
Age-standardised death rate attributable to household air pollution and ambient air pollution (per 100,000 population)	96.3	●	••
Percentage of surviving infants who received 2 WHO-recommended vaccines (%)	70.0	●	↑
Healthy Life Expectancy at birth (years)	64.8	●	↑
Subjective Wellbeing (average ladder score, 0-10)	4.2	●	••
SDG4 – Quality Education			
Net primary enrolment rate (%)	85.4	●	↑
Mean years of schooling (years)	2.6	●	→
Literacy rate of 15-24 year olds, both sexes (%)	55.0	●	••
SDG5 – Gender Equality			
Proportion of women aged 20-24 years who were married or in a union before age 18	40.3	●	••
Proportion of girls and women aged 15-49 years who have undergone female genital mutilation/cutting, by age	65.2	●	••
Seats held by women in national parliaments (%)	38.8	●	↑
Women in ministerial positions (%)	10.0	●	••
Estimated demand for contraception that is unmet (% women married or in union, ages 15-49)	36.6	●	↑
Ratio of female to male mean years of schooling of population age 25 and above (%)	43.2	●	••
Ratio of female to male labour force participation rate	87.9	●	→
SDG6 – Clean Water and Sanitation			
Population using at least basic drinking water services (%)	NA	●	••
Population using at least basic sanitation services (%)	7.1	●	→
Freshwater withdrawal as % total renewable water resources	11.6	●	••
Imported groundwater depletion (m^3/year/capita)	1.3	●	••
SDG7 – Affordable and Clean Energy			
Access to electricity (% population)	27.2	●	→
Access to clean fuels & technology for cooking (% population)	2.0	●	→
Renewable energy share in the total final energy consumption	92.7	●	→
Consumer affordability of electricity	50.0	●	••

SDG8 – Decent Work and Economic Growth	Value	Rating	Trend
5-year average GDP growth per capita (%)	6.7	●	••
Employment-to-population ratio	78.6	●	→
Slavery score (0-100)	80.0	●	••
Adults (15 years and older) with an account at a bank or other financial institution or with a mobile-money-service provider (%)	34.8	●	••
Starting a Business score	68.4	●	↑
SDG9 – Industry, Innovation and Infrastructure			
Infrastructure score (0-100)	37.5	●	••
Logistics performance index: Quality of trade and transport-related infrastructure (1=low to 5=high)	2.1	●	••
Research and development expenditure (% GDP)	0.6	●	••
Number of scientific and technical journal articles (per 1,000)	0.0	●	••
Mobile broadband subscriptions (per 100 inhabitants)	5.2	●	→
Proportion of the population using the internet (%)	15.4	●	↗
SDG10 – Reduced Inequalities			
Gini Coefficient adjusted for top income (1-100)	NA	●	••
SDG11 – Sustainable Cities and Communities			
Proportion of urban population living in slums	73.9	●	••
Improved water source, piped (% urban population with access)	86.0	●	→
Satisfaction with public transport (%)	41.0	●	••
Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5) in urban areas (µg/m^3)	35.7	●	↓
SDG12 – Responsible Consumption and Production			
Municipal Solid Waste (kg/year/capita)	0.3	●	••
E-waste generated (kg/capita)	0.5	●	••
Natural Resource Value Realization Score	45.7	●	••
Production-based SO_2 emissions (kg/capita)	0.4	●	••
Anthropogenic wastewater that receives treatment (%)	0.0	●	••
Net imported SO_2 emissions (kg/capita)	0.3	●	••
SDG13 – Climate Action			
Climate Change Vulnerability Monitor (best 0-1 worst)	0.3	●	••
Energy-related CO_2 emissions per capita (tCO_2/capita)	0.1	●	→
Imported CO_2 emissions, technology-adjusted (tCO_2/capita)	0.1	●	••
CO_2 emissions embodied in fossil fuel exports (kg/capita)	0.0	●	••
SDG14 – Life Below Water			
Percentage of inadequately managed plastic waste	NA	●	••
Ocean Health Index Goal - Clean Waters (0-100)	NA	●	••
Ocean Health Index Goal - Biodiversity (0-100)	NA	●	••
Ocean Health Index Goal - Fisheries (0-100)	NA	●	••
Mean area that is protected in marine sites important to biodiversity (%)	NA	●	••
Percentage of Fish Stocks overexploited or collapsed by EEZ (%)	NA	●	••
Fish caught by trawling (%)	NA	●	••
SDG15 – Life on Land			
Mean area that is protected in terrestrial sites important to biodiversity (%)	19.8	●	→
Percentage change in forest area (2010-2015)	0.2	●	••
Red List Index of species survival (0-1)	0.8	●	→
Imported biodiversity threats (threats/capita)	0.2	●	••
SDG16 – Peace, Justice and Strong Institutions			
Homicides (per 100,000 people)	7.6	●	••
Conflict-related deaths per 100,000	0.1	●	↗
Proportion of the population who feel safe walking alone at night in the city or area where they live (%)	66.0	●	↓
Children 5–14 years old involved in child labour (%)	27.4	●	••
Property Rights (0-100)	44.5	●	↓
Access to justice (0-100)	53.9	●	↓
Corruption Perception Index (0-100)	35	●	→
Public Sector Accountability & Transparency (0-100)	66.1	●	↗
Birth registrations with civil authority, children under 5 years of age (%)	2.7	●	••
SDG17 – Partnerships for the Goals			
Tax revenue (% GDP)	14.7	●	→
Government Health and Education spending (% GDP)	9.7	●	••
Level of customs duties on imports	8.9	●	••
Visa Requirement score	154.0	●	••
Governmental Statistical Capacity	70.0	●	↓

Figure 3.6. Ethiopia performance by indicator.

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

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References

Adimassu, Z., Kessler, A. and Stroosnijder, L. 2014. Farmers' strategies to perceived trends of rainfall and crop productivity in the Central Rift Valley of Ethiopia. *Journal of Environmental Development*, Vol. 11, pp. 123–40.

AGRA. 2014. *Africa Agriculture Status Report 2014: Climate Change and Smallholder Agriculture in Sub-Saharan Africa*. Nairobi, AGRA.

Altenburg, T. 2010. *Industrial Policy in Ethiopia*. Bonn, Germany, DIE.

Atakure, A. 2012. Climate change and variability in North Shoa Zone of Ethiopia: Impacts on crop production and farmers' local adaptation skills. M.Sc. thesis, Addis Ababa University, Ethiopia.

Belwal, R. and Teshome, H. 2011. Chat exports and the Ethiopian economy: Opportunities, dilemmas and constraints. *African Journal of Business Management*, Vol. 5, pp. 3635–48.

Boon, W. P. C., Moors, E. H. M., Kuhlmann, S. and Smits, R .E. H. M. 2011. Demand articulation in emerging technologies: Intermediary user organisations as co-producers. *Research Policy*, Vol. 40, pp. 242–52.

Climate and Development Knowledge Network (CDKN). 2012. *Managing Climate Extremes and Disasters in Africa: Lessons from the SREX Report*. CDKN. Available at: www.cdkn.org/srex.

CRGE. 2011. *Ethiopia's Climate Resilient Green Economy: Green Economy Strategy*. The Federal Republic of Ethiopia, http://www.undp.org/content/dam/ethiopia/docs/Ethiopia%20CRGE.pdf

CSA. 2015. *Agricultural sample survey: Key findings of 2014/2015.* Addis Ababa, Central Statistical Agency.

Diaz-Carretero, I. 2017. Environmental uses of zeolites in Ethiopia. *Catalysis Today*, Vol. 285, pp. 29–38.

EBI. 2014. *Ethiopia's Fifth National Report to the Convention on Biological Diversity*. Addis Ababa, Ethiopian Biodiversity Institute.

EBI. 2015. *Ethiopia's National Biodiversity Strategy and Action Plan 2015–2020*. Addis Ababa, Ethiopian Biodiversity Institute.

EPA. 2012. *National Report of Ethiopia*. United Nations Conference on Sustainable Development (Rio+20). Addis Ababa, Environmental Protection Authority, p. 73.

EPDC. 2014. *National Education Profile: Ethiopia, 2014 Update*. Washington DC, Education Policy and Data Center. Available at: http://www.epdc.org/sites/default/files/documents/EPDC%20NEP_Ethiopia.pdf

Federal Democratic Republic of Ethiopia (FDRE). 1997. *Environmental Policy of Ethiopia*. Addis Ababa, EPA, p. 29. Available at: https://theredddesk.org/sites/default/files/environment_policy_of_ethiopia_1.pdf

FDRE. 2003. *Rural Development Policy and Strategies*. Addis Ababa, Ministry of Finance and Economic Development.

FDRE. 2007. *Climate Change National Adaptation Programme of Action of Ethiopia*. Addis Ababa, FDRE via the Ministry of Water Resources and the National Meteorological Agency, p. 96.

FDRE. 2010. *National Science, Technology and Innovation Policy: Building Competitiveness through Innovation*. Addis Ababa, FDRE, p. 20.

FDRE. 2011*a*. *Ethiopia's Climate-Resilient Green Economic Strategy*. Addis Ababa, FDRE, p. 188.

FDRE. 2011*b*. *Ethiopia's Growth and Transformation Plan*. Addis Ababa, FDRE.

FDRE. 2015. *Intended Nationally Determined Contribution (INDC) of the Federal Democratic Republic of Ethiopia*. Addis Ababa, FDRE. http://www4.unfccc.int/Submissions/INDC/Published%20Documents/Ethiopia/1/INDC-Ethiopia-100615.pdf

FDRE. 2017. *Climate Change Education Strategy of Ethiopia and Priority Actions for 2017–2030*. Addis Ababa, FDRE via the Ministry of Environment, Forests and Climate Change and the Ministry of Education. Available at: https://www.unitar.org/ethiopia-launches-implementation-its-national-climate-change-education-strategy-and-priority-actions and https://www.uncclearn.org/national-projects/un-cclearn-ethiopia

Forum for Environment. 2010. *Ethiopia's Environment Review*. Addis Ababa, Forum for Environment.

Franks, P., Hou-Jones, X., Firkreyesus, D., Sintayehu, M., Mamuye, S., Danso, E. Y., Meshack, C. K., McNicol, I. and Van-Soesbergen, A. 2017. *Reconciling Forest Conservation with Food Production in Sub-Saharan Africa: Case Studies from Ethiopia, Ghana and Tanzania*. London, IIED. Available at: http://pubs.iied.org/17605IIED

Gebreeyesus, M. and Mohnen, P. 2013. Innovation performance and embeddedness in networks: Evidence from the Ethiopian footwear cluster. *World Development*, Vol. 41, pp. 302–16.

Getu, M. 2009. Ethiopian floriculture and its impact on the environment: Regulation, supervision and compliance. *Mizan Law Review*, Vol. 3, No.2, pp. 240–70.

GTP. 2013. *Growth and Transformation Plan, Annual Progress Report for FY 2011 – 2012*. Addis Ababa, Ministry of Finance and Economic Development.

International Organisation for Knowledge Economy and Enterprise Development (IKED). 2006. *Ethiopia: Innovation and Growth in International Comparison*. Prepared for Triple Helix Conference on Transforming University-Industry-Government Relations in Ethiopia, 29–31 May. Addis Ababa, IKED.

IPCC. 2012. Field, C.B, Barros, V., Stocker, T. F., Qin, D., Dokken, D. J., Ebi, K. L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S. K., Tignor, M. and Midgley, P. M. (eds), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Summary for policymakers*. Cambridge and New York, Cambridge University Press, pp. 1–19.

IUCN. 2014. *The IUCN Red List of Threatened Species*. www.iucnredlist.org/

Lal Kansal, M., Adeba, D. and Tyagi, A. 2014. *Challenges of Sustainable Development and Management of Water Resources in Ethiopia*. World Environmental and Water Resources Congress 2014, Portland (US). Available at: http://ascelibrary.org/doi/abs/10.1061/9780784413548.098.

López-Avilés, A., Feyissa, A. and Tessema, S. 2013. Project Evaluation Reports: Bati Jatropha plantation and biofuel project; Tekeze Reservoir buffer zone rehabilitation project; Myliham biogas and micro-dam project; Lake Logo sustainable land management and fisheries project; Kebena River restoration project; Guna Mountain rehabilitation project; and Environmental education in Debre Markos schools project. *African Adaptation Programme (AAP) in Ethiopia: Climate Change Knowledge Management and Communications Strategy*. UNDP, UNICEF and Government of Japan. A description of the Project can be found at: http://www.et.undp.org/content/ethiopia/en/home/operations/projects/climateriskandresilience/project_AAP

López-Avilés, A., Leta, S. and Tadesse, W. 2019. How sustainability is understood in Ethiopia and proposals for measuring environmental sustainability tailored for Ethiopia (forthcoming).

Mekonnen, M. M. and Hoekstra, A. Y. 2010. *The Green, Blue and Grey Water Footprint of Farm Animals and Animal Products*. Value of Water Research Report, Series 48, Vol.1. Delft, Netherlands, UNESCO-IHE.

Mekonnen, M. M. and Hoekstra, A.Y. 2012. A global assessment of the water footprint of farm animal products. *Ecosystems*, Vol. 15, pp. 401–15.

Meshesha Fenta, T. 2014. Demands for urban public transportation in Addis Ababa. *Journal of Intelligent Transportation and Urban Planning*, Vol. 2, No. 3, pp. 81–88.

Nwuke, K. 2015. *Science, Technology and Innovation Policy in Africa in the Age of Brilliant and Disruptive Technologies: An Analysis of Policies at the National, Regional and Continental Levels*. Background paper for ARIA VII. Addis Ababa, Economic Commission for Africa.

Padilla-Pérez, R. and Gaudin, Y. 2013. Science, technology and innovation policies in small and developing economies: The case of Central America. *Research Policy*, Vol. 43, pp. 749–59.

Regassa, N., Sundaraa, R. D. and Bogale-Seboka, B. 2011. Challenges and opportunities in municipal solid waste management: The case of Addis Ababa City, central Ethiopia. *Journal of Human Ecology*, Vol. 33, No.3, pp. 179–90.

Rockström, J., Steffen, W., Noone, K.,Persson, A., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J. A. 2009. A safe operating space for humanity. *Nature*, Vol. 461, pp. 472–75.

SDGCA&SDSN (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York. The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network 2018. Available at http://africasdgindex.org and http://unsdsn.org/wp-content/uploads/2018/07/AFRICA-SDGS-2018-Complete-Report-WEB.pdf

Smits, R. E. H. M. 2002. Innovation studies in the 21st century, questions from a user's perspective. *Technological Forecasting and Social Change*, Vol. 69, pp. 861–83.

Sorecha E. M. 2017. Climate projection outlook in Lake Haramaya watershed, eastern Ethiopia. *Hydrol Current Res*, Vol. 8, p. 275.

Tadesse, W. and Desalegn, G. 2013. The state of science and technology in forestry and agroforestry in Ethiopia. B. Gebrekidan, S. Debela, S. Bekure, T. Bezuneh, S. Hailemariam and G. Zeleke (eds), *Proceedings of the Workshop on The State of Agricultural Science and Technology in Ethiopia*, pp. 413–48.

Tadesse, M. 2004. Asteraceae (Compositea). I, Hedeberg, Ib Friis and S. Edwards (eds.), *Flora of Ethiopia and Eritrea*, Vol. 4 Part 2. Addis Ababa and Uppsala, The National Herbarium, Addis Ababa University.

Teketay, D., Lemenih, M, Bekele, T., Yemishaw, Y., Feleke, S., Moges, Y., Hunde, T. and Nigussie, D. 2010. Forest resources and challenges of sustainable forest management and conservation in Ethiopia. F. Bongers and T. Tennigkeit (eds), *Degraded Forests in Eastern Africa, Management and Restoration*, London, Earthscan Ltd, pp. 19–63.

UNDP. 2015. *National Human Development Report 2014. Ethiopia.* Addis Ababa, UNDP. http://hdr.undp.org/sites/default/files/nhdr2015-ethiopia-en.pdf

UNECA. 2016. Africa's science, technology and innovation policies – national, regional and continental. *Assessing Regional Integration in Africa VII (ARIA VII): Innovation, Competitiveness and Regional Integration*, p.83. http://www.uneca.org/sites/default/files/PublicationFiles/aria7_eng_chap5.pdf

UNESCO. 2015. *Mapping Research and Innovation in the Republic of Rwanda*. GO→SPIN Country Profiles in Science, Technology and Innovation Policy, Vol. 4. Paris, UNESCO.

UNESCO-Sida. 2017. *Building and Mobilizing Developing Country Capacity to Participate Effectively in the Future Earth Initiative, Country Report from Ethiopia*. Paris, UNESCO.

UNSDSN (2017), 'Sustainable Development Goals Index and Dashboards Report of 2017'(http://unsdsn.org/resources/publications/sdg-index-and-dashboards-report-2017)

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network. Available at http://africasdgindex.org

Wakeford, J. J., Gebreeyesus, M., Ginbo, T., Yimer, K., Manzambi, O., Okereke, C., Black, M., and Mulugetta, Y. 2017. Innovation for green industrialisation: An empirical assessment of innovation in Ethiopia's cement, leather and textile sectors. *Journal of Cleaner Production*, Vol. 166, pp. 503–11.

Woody Biomass Inventory and Strategic Planning Project (WBISPP). 2004. *A Strategic Plan for the Sustainable Development, Conservation and Management of the Woody Biomass Resources of Ethiopia: Final Report*. Addis Ababa, Ministry of Agriculture, FDRE.

Weldegiorgis, K. A. 2015. Analysis of science, technology, and innovation policy and its challenges in Ethiopia; an emphasis on the role of HEIs. *International Journal of Current Research*, Vol. 7, No.1, pp. 11792–803.

World Bank. 2011. *Ethiopia – Joint Staff Advisory Note on Growth and Transformation Plan (GTP), 2010/11–2014/15*.Washington, DC, World Bank. http://documents.worldbank.org/curated/en/796761468255282515/Ethiopia-Joint-staff-advisory-note-on-Growth-and-Transformation-Plan-GTP-2010-11-2014-15

World Bank. 2016. *Ethiopia's Great Run: The Growth Acceleration and How to Pace It*. Washington, DC, World Bank Group, pp. 148.

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4

Co-designing knowledge systems for sustainable development in Kenya

4. Co-designing knowledge systems for sustainable development in Kenya

Elsie Onsongo,
Emmanuel Mutisya,
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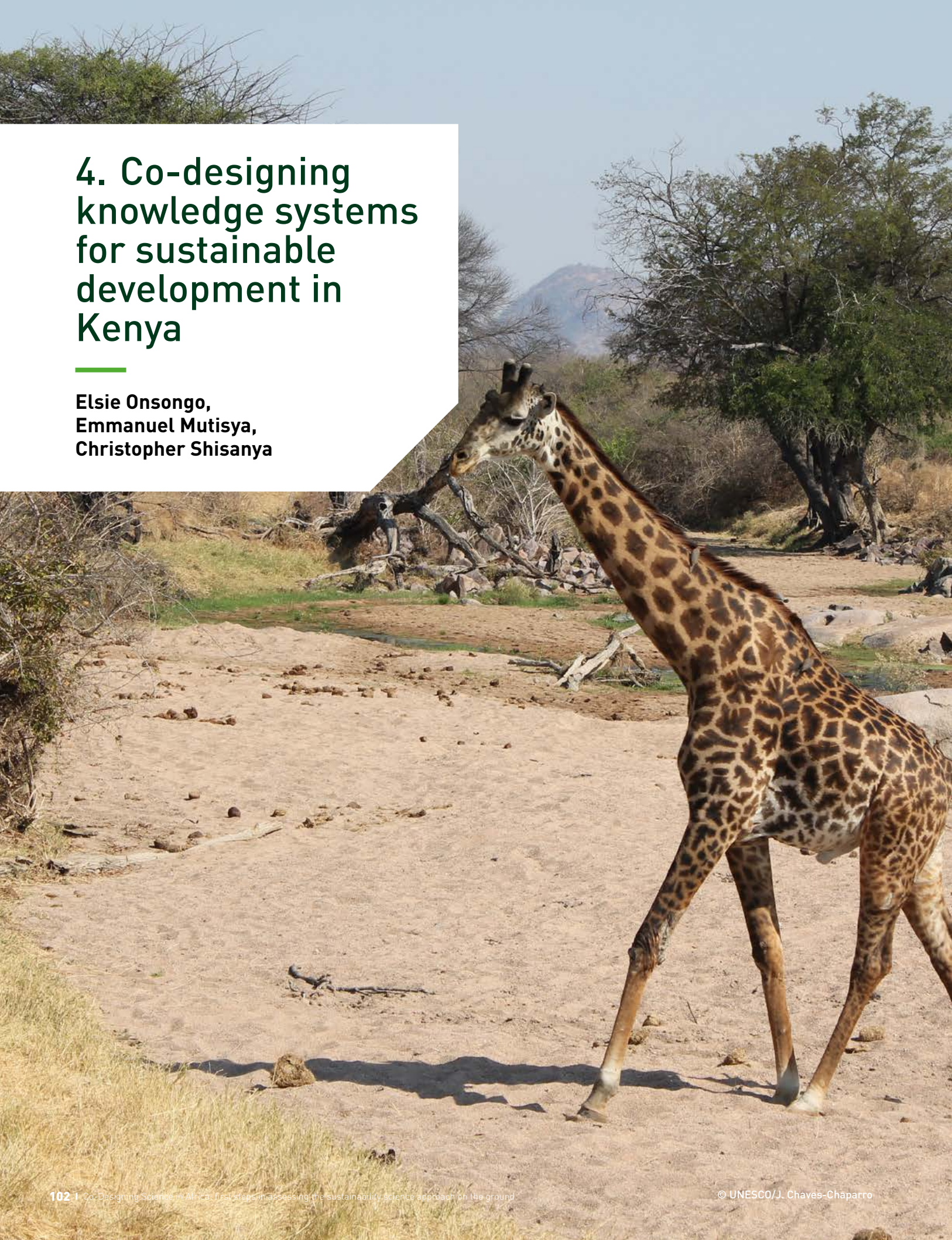

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4.1. Introduction

In Kenya's endeavour to transition to an industrialized country, sustainable development is increasingly becoming an area of focus. Research in this area is gaining a lot of attention, with various policies now highlighting sustainability as a critical element. Further, other actors within the innovation system in Kenya – including the private sector, civil society and development partners – are championing sustainable development more overtly and focusing on more collaborative efforts to develop solutions tailored to local sustainability problems. This gradual but palpable shift in the collective psyche of the national innovation system in Kenya becomes crucial when sustainability challenges are exacerbated. Factors such as rising poverty levels and inequality, population growth, urbanization and rapid industrialization, if unchecked, will lead to further depletion of natural resources, deterioration of the environment and thus, quality of life.

In terms of culture, Kenya is a very rich country and, like many other African countries, has many different ethnic groupings, mainly the Bantu, the Nilotic and the Cushitic, Arabs, Indians and Europeans. The country's total land area covers 569,140 km^2 and the population as of April 2018 stands at 50,662,612.[1]

Since independence, Kenya has pursued various pathways to development. To a large extent, efforts by the Kenyan government to meet the aspirations of pre- and post-independence generations have been inhibited by a preoccupation with crises, relief and drought engagement. In addition, the central planning and structural adjustment programmes adopted have failed to promote development management and achieve national development goals.

Following Kenya's adoption of the Sustainable Development Goals and Agenda 2063: The Africa We Want in the international arena, and the Constitution of Kenya 2010 and Kenya Vision 2030, local consensus is emerging on the need to adopt long-term perspectives as an appropriate framework for promoting sustainable development, and to involve multiple stakeholders in that endeavour. This perspective is evident in the legislation, policy objectives and strategies developed in various sectors in Kenya, with efforts to stimulate cross-sectoral collaboration at a nascent stage.

In considering new strategies to tackle this governance challenge or exploring new social or economic models of development, sustainability science, as discussed in the introductory chapter of this book, offers a potentially novel approach. Kenya, like many countries and regions in Africa and the rest of the Global South, features multiple knowledge systems that have implications for research and education for sustainable development. These knowledge systems, if mobilized effectively, have the capacity to generate context-relevant knowledge that could effectively address local sustainability challenges.

Formal science and education systems modelled on the Western scientific approach are widely perceived as a fruitful avenue to generate new knowledge in this regard and thus have received a great deal of attention from policy-makers, academics and some practitioners. Accordingly, the Kenya national innovation system – as perceived by the National Commission for Science, Technology and Innovation (NACOSTI) and related policy actors – is modelled around research and innovation in the formal domain.

Experiential knowledge from the informal sector and from traditional knowledge systems, which are difficult to codify and measure, is somewhat overlooked and undervalued relative to the Western scientific approach. Yet, there is evidence that indigenous and local knowledge systems, which have been developed over a long period of time through experimentation, adaptation and coevolution, provide valid and useful theories, methods and practices for sustainable development. We assert that further progress towards understanding and tackling 'wicked problems' in the local and global context could be achieved by recognizing complementarities across these knowledge systems. Such an approach would provide new insights for sustainability science and how it can be mobilized in developing countries such as Kenya.

In this chapter, we briefly discuss the social, economic and environmental sustainability challenges that have been facing Kenya. We then highlight how national legislation, policies and strategies developed in different sectors address these sustainability challenges, while discussing the challenges of implementing these policies in the current context. Despite these challenges, most of them arising from deficiencies in the governance framework, the chapter shows that Kenya has invested considerable effort in developing legislation, policies and strategies that explicitly integrate sustainable development as a central national value and an explicit principle of governance.

The chapter subsequently maps Kenya's science, technology and innovation policy framework and the underlying national innovation system. Gaps in the system that inhibit its potential towards addressing sustainable development are identified. A key gap is the underdeveloped cooperation within and among existing knowledge systems/actors: inside industry, between firms, universities and research institutions, and between formal or 'Western' science and indigenous and local

knowledge systems, and even between different locally-specific indigenous knowledge systems. Instances are also identified where cooperation is being fostered through policy instruments and ad hoc projects. In this regard, three illustrative case studies are highlighted, in which a co-designed collaborative interdisciplinary approach to research and innovation was adopted: on frugal innovation in weather prediction, education for sustainable development, and organic agriculture. The chapter concludes by providing some policy recommendations to foster the co-design of research and innovation for Kenya's sustainable development.

Photo 4.1. Lions in Masaai Mara reserve. With 65 national reserves and parks, wildlife tourism contributed 9,8% of GDP in 2016 in Kenya.
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4.2. Kenya's socio-economic landscape

Kenya is a lower middle-income economy in sub-Saharan Africa with a population of 47.3 million (2017). As the largest and most advanced economy in East and Central Africa with a gross domestic product (GDP) of US$69.2 billion and per capita (PPP) of US$3,207.70, Kenya has made significant structural and economic reforms that have contributed to sustained economic growth in the past decade. Kenya is often classified as a frontier or emerging market and has been ranked 80th on the 2017 Global Innovation Index (GII).[2]

Given its robust and consistent economic performance in recent years, with an estimated growth of 5.8% in 2018,[3] Kenya's medium- to long-term economic outlook has been positive. Key drivers for this growth originate from its vibrant services sector, enhanced construction, currency stability, low inflation, low fuel prices, a growing middle-class and rising incomes, a surge in remittances, and increased public investment in energy and transportation. However, the economy is still vulnerable to persistent risks such as famine and drought, fiscal slippages, uncertainties around currency exchange rates, and shocks associated with the political environment.

The services sector in Kenya has seen tremendous growth in recent years, and now accounts for up to 57% of GDP in 2016, as **Figure 4.1** illustrates. However, the agricultural sector – which employs 75% of the workforce – accounts for only 24% of GDP largely due to low yields, suboptimal land use, inefficient agricultural markets and low value addition. Manufacturing is the smallest sector, accounting for 19%. Policy-makers recognize the need to structurally transform the country's labour market from an overreliance on agriculture to high-productivity sectors, such as services and manufacturing.

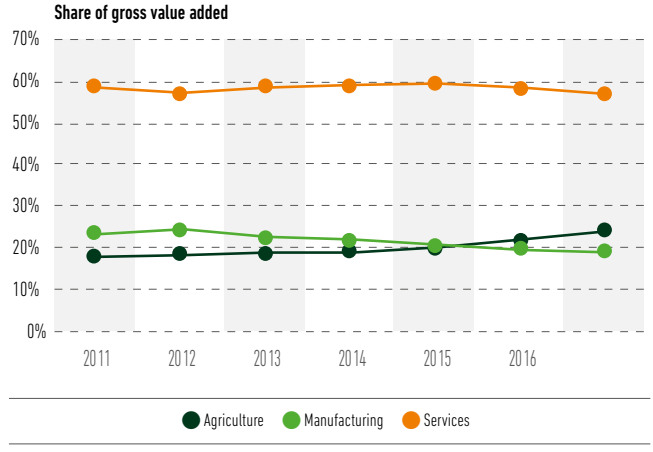

Figure 4.1. Sector share growth, 2011–2016.
Source: Calculated from KNBS and SID, 2017.

In general, on the social front, Kenya has made modest progress in improving the different social indicators. The country has met some of the Millennium Development Goals (MDGs) targets such as reduced child mortality, near universal primary school enrolment, and narrower gender gaps in education. Additionally, healthcare and free maternal healthcare at all public health facilities are expected to improve health outcomes and develop a more equitable healthcare system. Nevertheless, as will be discussed next, poverty levels and inequity have remained high over the years. Kenya has a Human Development Index (HDI) of 0.548, which gradually increased from 0.447 in 1999, which puts

2 https://www.globalinnovationindex.org/gii-2017-report
3 World Bank (2017).

the country in a low human development category and gives it a world rank of 145 out of 188 countries.

Kenya's sustainable development and overall development strategy and plans are anchored in the Kenya Vision 2030 – the country's new development blueprint covering the period 2008 to 2030 (GoK, 2008). It aims to transform Kenya into a newly industrializing, upper middle-income country providing a high quality of life to all its citizens by the year 2030. The Vision has been developed through an all-inclusive and participatory stakeholder consultative process, involving Kenyans from all parts of the country. Kenya Vision 2030 is being implemented in successive five-year medium-term plans starting in 2012.

This long-term development blueprint is based on three pillars, as illustrated in **Figure 4.2**: an economic pillar, which aims at economic growth of 10% per annum; a social pillar, which seeks just, cohesive and equitable social development in a clean and secure environment; and a political pillar, which aims to install an issue-based, people-centred, results-oriented and accountable political system that respects the rule of law and protects the rights and freedoms of every Kenyan. Among other sectors such as energy, security and the public sector, the strategy highlights science, technology and innovation (STI) as a key sector for reform. An alignment to sustainable development is strongly discernible in the formulation of the Medium-Term Plans for all flagship projects under each pillar (GoK, 2008).

Photo 4.2. School students visiting biodiversity park in Mombasa (Kenya)
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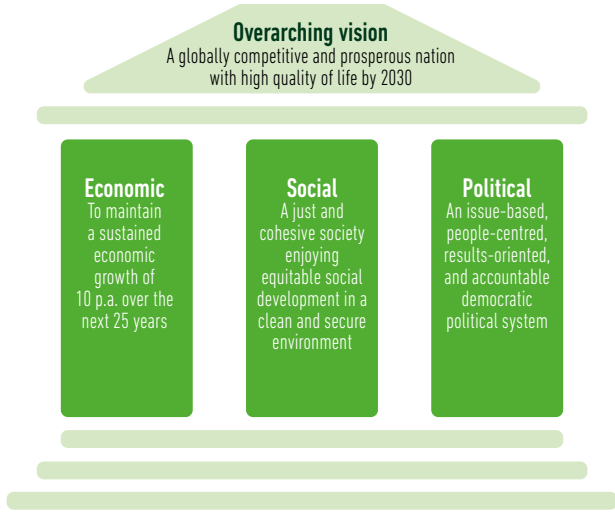

Figure 4.2. Kenya's Vision 2030.
Source: GoK, 2008.

4.3. Main sustainability challenges facing Kenya

4.3.1. Social and economic sustainability problems

Kenya's social development has been improving over the last decade, with some MDG targets met, among them reduced child mortality and a reduction in the gender gap in education. However, most national policy documents still show that women, youth, rural communities and other vulnerable groups, such as livestock farmers, still suffer higher levels of exclusion in accessing resources and in decision-making processes. Below, we outline some of the socio-economic challenges.

Poverty

Kenya's sector-specific development policies and strategies highlight cross-cutting sustainability issues, the most recurrent being poverty and inequality. Currently, 45.2% of the Kenyan population live below the poverty line.[4] Above all, the lack of income and resources at household and community level inhibits the realization of sustainable livelihoods, prosperity and participation. Other factors include lack of access to education and other basic services, limited economic diversity and possibilities, political instability and the exclusion of the majority of households in public policy processes.

Inequality

Although Kenya has experienced robust economic growth in recent years, this growth has only benefited parts of the population, leaving out others. The national Gini coefficient is estimated at 0.445 which reflects a high level of inequality (KNBS and SID, 2013). A 2014 report estimated that less than 0.1% of the population (≈ 8,300 people) own more wealth than the bottom 99.9%.[5] This is attributed to disproportional benefits for the high-income segment, e.g. corporate tax exemptions and incentives running up to US$1.1 billion a year. Kenya's high levels of inequality are reflected in many spheres, for instance in healthcare, where a quarter of the population cannot access care due to poverty, and nearly a million children are out of school. Further, gender inequality is reflected in asset ownership, where only 6% of women hold a land title deed.

Unemployment

The unemployment rate for the Kenyan population of working age stands at 39.1%, most of whom are the youth.[6] Only a few young people joining the labour market can find a job in the formal sector, and many cannot readily find an adequate occupation in the informal sector (UNDP, 2013). The economic growth rate has not been able to keep pace with the expanding labour force. Besides addressing joblessness, government policies must also focus on the issue of job quality and youth inactivity.

Health

Health is one of the central concerns for sustainable development. Despite Kenya's advances in some areas of healthcare delivery, poor health continues to be a constraint on the country's development efforts. Life expectancy at birth stands at 64.1 years for women and 60.3 years for men. Of the total deaths, 64% are caused by communicable maternal, perinatal and nutritional conditions, while 10% are caused by injury, and 27% by non-communicable diseases.[7] Contagious diseases like malaria and HIV/AIDS affect the young labour force and create over-dependency, which has a negative impact on productivity and the growth of the economy. Health expenditure, however, remains at less than 5% of GDP, with most of it spent on curative rather than preventative healthcare. This disproportionate economic commitment to tackling health, and subsequently NCDs, highlights the need for more action in this key area.

Energy

Kenyan energy sources have been typically derived from the domestic environment rather than from imports. Fuel wood accounts for 70% of all energy consumed (in rural areas, it accounts for as much as 90% of energy use), while electricity supplies 6% of the country's energy, of which hydropower sources represent more than 64%. Hydropower is derived directly from the forested catchments of Kenya's five 'water

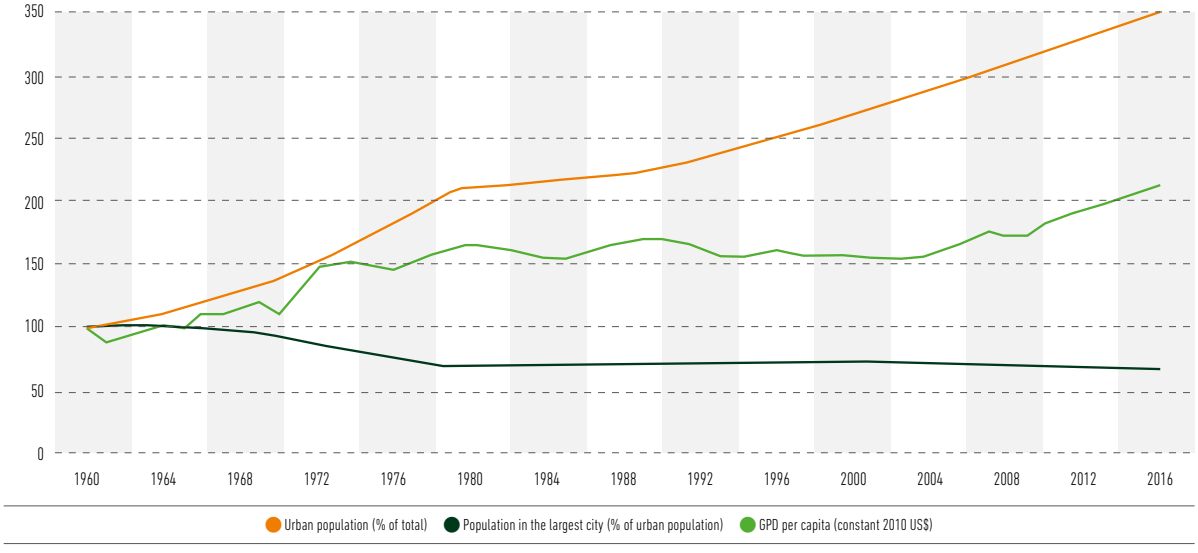

Figure 4.3. Urbanization and per capita GDP in Kenya, 1960–2015.

Source: taken from Shifa, M. Leibbrandt, M. (2017) Urban Poverty and Inequality in Kenya. Urban Forum December 2017, Volume 28, Issue 4, pp 363–385 https://doi.org/10.1007/s12132-017-9317-0. With permission SPRINGER Nature (Copyright Clearence Center - Rights Link).

5 New World Wealth (2014).

6 Human Development Report (2016).

7 WHO (2014).

towers'. Deforestation of their slopes has had a direct impact on the amount of water available to generate power. Similarly, electricity power rationing occurs during prolonged droughts, and has often led to the closure of several industries, with negative consequences for employment and GDP.

Rapid urbanization

Kenya is experiencing rapid urban population growth, with more than 25% of the population living in urban areas in 2015. This growth is not accompanied by concomitant socio-economic growth and environmental development (see **Figure 4.3**). Kenya's urban population concentration has also led to increased social, economic and environmental strains, with a significant percentage of urban dwellers living in sprawling slums (Mutisya and Yarime, 2014), which is posing a big challenge to the diminishing available resources, environmental quality and human well-being. Kenya's urbanization is occurring due to several reasons: 55% due to increasing birth rate in urban areas, and 25% due to rural-urban migration caused by drought, conflict, rural poverty and the search for opportunities (Mutisya and Yarime, 2011). With a projected sustained annual urban population growth rate of more than 3% in the next 30 years, Kenya stands to face major sustainability challenges if a new roadmap to mitigate these challenges is not implemented.

4.3.2. Environmental sustainability problems

Kenya is facing many environmental challenges, including deforestation, soil erosion and land degradation, desertification and loss of biodiversity, water scarcity, and pollution from industry. The challenges are exacerbated by poverty, floods, droughts and other related risks associated with climate change, thereby threatening national security and increasing societal and national economic vulnerability. These environmental factors cut across all sectors of the economy and contribute directly or indirectly towards achieving the other development goals. Thus, Kenya has mainstreamed environmental concerns into its national and sectoral planning. **Table 4.1** in the following section details the environmental challenges facing different sectors.

4.4. National policies that address sustainability problems

Environmental protection cuts across all other sectors and contributes directly or indirectly towards achieving any development goals. Due to the importance of environmental sustainability, this has been mainstreamed into national and sectoral policies and planning.

Kenya's post-independence development policies and strategies focused mainly on socio-economic development and were characterized by poor governance, as evidenced by corruption, ethnic conflicts, insecurity, political uncertainty and poverty. This resulted in the alienation of large sections of society from the mainstream economy, social exclusion, inequality, wasteful public investments, massive poverty, ethnic animosity and cut-throat political competition and intolerance.

Earlier government focus on sustainable development is outlined in the Development Plan for 1970–74, in which the rural-urban policy was anchored. The emphasis of this policy was the development of physical infrastructure, promotion of small towns serving rural areas, improvement of public services delivery, and incentives for businesses (Evans, 1989). A more explicit sustainable development focus was outlined in the National Development Plan for 1993–1997, which enhanced the role and contribution of rural-urban activities to economic development, in order to improve living conditions. In the two development plans, however, the concerns were never translated into a much-needed coherent sustainable development policy (Bousquet, 2008). In addition, the plans lacked a clear-cut response to environmental problems, entirely focusing on socio-economic and political development.

The National Development Plan of 2002–2008 concentrated for the first time on environmental sustainability for development. The plan's objective was to improve living conditions in slums, promote urban safety and protect the rights of marginalized groups. It was envisaged that the policy was key to guiding sustainable development, including land use and management, environmental conservation, urban governance and management, urban investment and delivery of services (RoK, 2008). However, the plan was not fully implemented, and its development problems were not fully addressed.

As already mentioned above, the government's commitment to sustainable development is explicitly outlined in Kenya's Vision 2030. The vision, which has been developed through an all-inclusive country-wide stakeholder consultative process,

recognizes Kenya as a country in need of properly streamlined policies addressing the various existing sustainability challenges (GoK, 2008). To augment this, and with the enactment of a new constitution, Kenya has endorsed and adopted Agenda 21, and ratified most of the international agreements, treaties, conventions and protocols resulting from the first Rio conference in 1992 that are in harmony with the country's plans for sustainable development.

As shown in **Table 4.1**, Kenya has invested considerable efforts in developing legislation, policies and strategies to address its developmental challenges. Sustainable development is consistently cited as a central national value and an explicit principle of governance across sectors. The main challenge has been the implementation of the policies and strategies, largely due to institutional weaknesses that continue to delay progress.

Another major challenge is a lack of coordination and harmony among statutes, both within and across sectors, and between the national government and county governments. Some strategic documents cite the lack of a mandate – or overlap of mandates across institutions – to implement programmes, and institutional inertia. Budgetary constraints and suboptimal resource allocations attributed to competition for resources among sectors limits the scale of programmes implemented. Poor monitoring and evaluation mechanisms, lack of human resource capacity and knowledge capacities, and inadequate technical infrastructure, such as comprehensive data collection and information management platforms, limit the technical and administrative efficacy of the agencies involved. The lack of incentive structures and enforcement mechanisms congruent with new policies contribute to stakeholder inertia.

Finally, corruption and abuse of power have been significant hindrances to effective policy implementation and are evidence of institutional failure. Government actors often disregard the prescriptions of regulatory and policy frameworks in order to attain short-term political objectives or fraudulently enrich themselves. Kenya loses a third of its state budget to corruption (Ethics and Anti-Corruption Commission, 2015). To fight corruption in public services, attempts to establish an ethics regime that fosters institutional integrity is being pursued, for instance through the Public Officer Ethics Act 2003 (revised in 2016).[8] In addition, the new constitution establishes principles and mechanisms that could enhance government accountability. However, as Akech (2011) asserts, this constitution's effectiveness depends on whether the statutory order will be transformed to conform to its principles and values.

Table 4.1. Sectoral policies in Kenya that address sustainability challenges.

Sector	Legislation, policies and strategies
Agriculture	• The Agriculture Act, Cap 318, (amended by Act 11 of 1993 and Act 2 of 2002) • Forests Act (2005) • National Food Policy (1991) • Food Security and Nutrition Policy (2011) • Rural Development Strategy, 2001–2016 • Agricultural Sector Development Strategy (ASDS) 2009–2020 • Various cash crop acts of law: coffee, tea sugar, cotton, pyrethrum
Water and sanitation	• The Water Act (2016) • The Irrigation Act, Cap 347 • National Water Policy (1999) • National Water Resources Management Strategy (NWSS) (2006) • National Water Services Strategy (NWSS) (2007–2015) • National Irrigation and Drainage Policy (2009) • Water Sector Strategic Plan (WSSP) (2010)
Natural resources	• Land • The National Land Commission Act (2012) • The Land Act (2012) • The Land Registration Act (2012) • National Land Policy (2009) • ASAL Development Policy • The Environmental Management and Co-ordination Act (EMCA) (1999)
	• Forestry • Forests Act (2005) • The Forest Policy (2014)
	• Fisheries • The Territorial Waters Act, Cap 371 • The Lakes and Rivers Act, Cap 409 • The Fisheries Management and Development Act (2016) • National Oceans and Fisheries Policy (2008)
	• Mining • The Mining Act (2016) • Mining and Minerals Policy (2016) • The Petroleum (Exploration and Production) Act (revised 1986) • Mineral Resources Strategic Plan for 2006–2010
Energy	• Sessional Paper No. 4 of 2004 • Energy Act No. 12 of 2006 • The Energy (Solar Water Heating) Regulations (2010) • The Energy Policy (2014) • Least-Cost Power Development Program (LCPDP) 2009–2029 • Rural Electrification Master Plan (REMP) • Renewable Energy Feed in Tariff (FiT)
Tourism and wildlife	• Wildlife Conservation and Management Act (2013) • The Kenya Tourism Development Corporation (KTDC) Act (1967) • National Tourism Policy (2013–2018) • The National Wildlife Conservation and Management Policy (2017)
Environment	• The Environmental Management and Coordination Act (EMCA) of 1999 • Climate Change Act • National Environment Policy (2013) • National Climate Change Response Strategy (NCCRS) (2010–2030) • National Disaster Management Policy (2009)

Source: Authors' own compilation

Sustainability challenges addressed	Selected policy objectives and strategies
Poverty and food insecurity, low productivity levels and inefficient markets, human wildlife conflict, land use, tension between subsistence and commercial farming, declining soil fertility, livestock diseases and pests, high variability of weather events (droughts, floods).	Develop and manage key factors of production to increase productivity, empower farmers, review taxation on agriculture, establish an efficient agricultural research system, develop an agricultural land use master plan, strengthen institutional framework for coordinating development in northern Kenya and other arid lands, environmental management.
Uneven temporal and spatial distribution of water, degraded water catchment areas, insufficient maintenance and deterioration of water infrastructure, pollution and degradation of water resources from uncontrolled effluent discharge, water use conflicts, underdeveloped irrigation potential, poor sanitation and sewerage infrastructure, health risks e.g. repeated outbreaks of water-related epidemics, weak institutional setup.	Decentralize water services, ground water conservation zones, formalize service provision, institute mandatory environmental impact assessment for all major water development activities, construct water storage facilities, build water resource management databases, harmonize policy and legislation, capacity development.
Inequitable access to land, environmental degradation, conflicts, unplanned proliferation of informal settlements, desertification, historical injustices, outdated legal and institutional framework, poor information management.	Land-use planning, computerize land information, recognize and protect land rights of minority communities and vulnerable groups, reform institutional framework, build capacity in communal land institutions, streamline land dispute institutions and mechanisms.
Increasing demand for land and forest resources, high levels of erosion, siltation and land degradation, climate change, ineffective regulatory mechanisms and inadequate law enforcement, inadequate funding.	Mainstream forest conservation into national land use systems, decentralize forest management, conserve forest genetic resources, rehabilitate and protect degraded forest ecosystems, water towers, catchment areas and other ecologically fragile areas, promote farm forestry and dry land forestry.
Excessive fishing effort, destructive fishing technologies, environmental degradation in some inland lakes and rivers, exploitation of offshore territorial waters, conflicts on resource use, gender rights issues and equity, stagnated aquaculture development, lack of safety at sea.	Research and development in fisheries conservation, aquaculture development, fish quality assurance and value addition, fisheries monitoring, control and surveillance, equitable distribution and long-term sustainable development of fisheries resources.
Inadequate geological data and information, underdevelopment of the mineral processing industry, lack of appropriate technology and high energy costs, inadequate funding for mineral exploration, environmental degradation from mining operations, gender issues and child labour, low local participation in large-scale mining, unclear fiscal regime.	Put in place a transparent, efficient and unified regulatory framework for the mining sector, enhance collection and access to geological data, develop legislative mechanisms for accessing land for mineral development, develop a fiscal regime, benefit sharing, enhance local participation, balance mining and environmental conservation, land restoration.
Low quantity and reliability of energy supply, high initial capital outlay for energy infrastructure (wind farms, photovoltaic panels, dams), high cost of energy, overreliance on wood fuel and charcoal from unsustainable sources, limited technical capacity and inadequate data, competing and conflicting interests in use of land and natural energy resources (e.g. biofuel plantations, dam reservoirs, etc.), hydrology and climate vulnerabilities, relocation and resettlement of affected persons.	Improve competitiveness, quantity, quality and reliability of energy supply, enforce protection of catchment areas, provide and create additional safeguards on utilization of natural resources for energy, enhance public participation in energy matters, establish inter-ministerial collaboration of relevant stakeholders, review institutional mandates, establish a National Energy Institute for training, research and development.
Accelerating loss of wildlife populations, degradation and fragmentation of habitats and loss of ecosystem functions, effects of climate change, the spread of invasive species and outbreaks of epizootic diseases, lack of coordinated enactment of sectoral policies in natural resource governance.	Develop a coordinated framework for wildlife management, conserve wildlife resources in national parks, national reserves and national sanctuaries, enhance ecological integrity of wildlife and their habitats through the integration of private and community lands into protected area systems, strengthen wildlife research, enhance sustainable tourism.
High population growth, rising poverty levels, shrinking productive land, unsustainable land use practices, poor soil and water management practices, deforestation, overgrazing and pollution, habitat destruction, unsustainable harvesting of natural resources, bio-piracy and introduction of invasive and alien species, poor waste management, disasters (droughts, fires, floods, technological accidents, diseases and epidemics).	Develop and implement national strategies for rehabilitation and restoration of degraded forest ecosystems, water catchment areas, wetlands, marine resources and mining sites, regulate bio-prospecting, promote eco- and organic farming, empower communities, ensure environment impact assessment for infrastructure and housing projects, document and value natural capital, mainstream environmental accounting, strengthen research and capacity, strengthen and enhance early warning and response systems for climate and disaster risk reduction.

4.5. Mapping Kenya's national research and innovation system and policy framework

In 1977, the National Council for Science and Technology (NCST) was established under the Science and Technology Act. In a bid to mainstream science, technology and innovation in all sectors of the economy, and to create a framework that would propel Kenya into a knowledge-based economy, a comprehensive Science, Technology and Innovation (STI) Policy and Strategy was developed in 2009. Within it, a prescriptive Kenya national innovation system (KNIS) was proposed as an integrative policy framework. KNIS is seen as a way to structure and increase coordination among different actors by introducing linkages between academia, industry and government to effectively support innovative activity in the country.

The STI Policy and Strategy process contributed to the development of the draft STI Bill in 2009 which was amended in 2012 in the context of the Kenya Constitution 2010 and Kenya Vision 2030, both of which highlight STI as a key basis for economic, political and social advancement. In 2013, the new Science, Technology and Innovation Act which detailed the organizational structure for STI governance at the national level were enacted. **Figure 4.4** identifies key actors and organizations within Kenya's innovation system.

4.5.1. The STI governance framework

The governance of STI is in the purview of the Ministry of Education. The department oversees the following three agencies and their functions:

- *National Commission for Science, Technology and Innovation (NACOSTI)*, which sets priorities for STI policy and coordinates STI activities at the national and county level.
- *Kenya National Innovation Agency (KENIA)*, which has the mandate to scout for and promote novel ideas from individuals and organizations, support incubation and commercialization, develop an intellectual property rights framework, develop a comprehensive innovation database, and facilitate the application process for research grants.
- *National Research Foundation (NRF)*, which is responsible for the mobilization of funds to facilitate research for the advancement of STI in collaboration with KENIA. The NRF manages the National Research Fund that awards grants, scholarships and bursaries, and allocates research funds to universities and research institutes.

A review of Kenya's STI policy framework and the underlying innovation system, however, reveals various challenges and system failures that dampen the momentum of development. There is still a lack of coordination within the STI governance framework, evidenced for instance by the duplication of roles

Photo 4.3. Kibera slum, Nairobi, Kenya

Kenya national innovation system

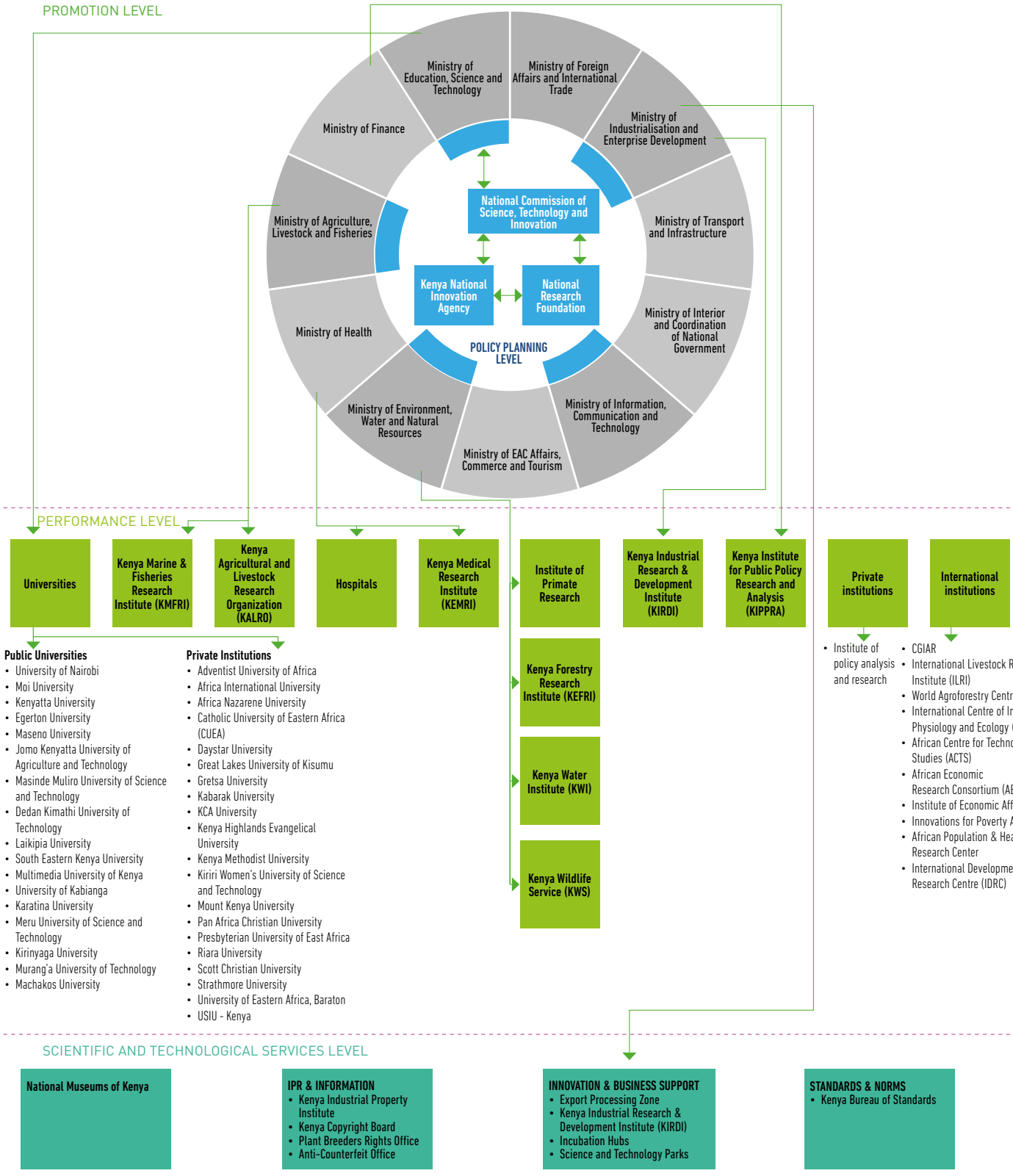

Figure 4.4. Organizational chart showing Kenya's research and innovation system.
Source: Authors' production based on GO→SPIN methodology (UNESCO, 2015)

between KENIA and NACOSTI. Other challenges include inefficient interlinkages among diverse actors in the innovation systems, lack of synergy in STI initiatives, and under-developed framework conditions. Despite these impediments, Kenya has risen to be one of the most innovative entrepreneurial hubs in Africa. As Ndemo (2015) argues, innovative activity in Kenya has largely taken place outside innovation policy. Instead, the policy framework has been catching up with innovation dynamics that have occurred organically, for instance in the ICT sector, where mobile application development was flourishing, and in the agricultural sector where research and development (R&D) is ongoing.

4.5.2. STI services

Intellectual property rights

Kenya has been investing efforts in developing a comprehensive intellectual property rights framework. Intellectual property rights (IPR) are managed and administered by four semi-autonomous institutions: the Kenya Industrial Property Institute (KIPI), the Kenya Copyright Board, the Plant Breeders Rights Office and the Anti-Counterfeit Office. A draft National Intellectual Property Policy and Strategy 2012–2017 has been developed to promote the generation, protection and commercialization of intellectual property. In addition, several universities and research institutes now have an IP Policy and Technology Transfer office. In establishing this new IP system, challenges such as a lack of transparency, reliance on inefficient manual information systems, a lack of skilled capacity and a lack of coordination and proper integration into the innovation system have been identified (Moraa et al., 2012). Thus, many actors in STI, particularly small business start-ups, still lack guidance and direction in IPR issues, and large corporations and research institutions are relatively inactive in utilizing the IPR system. The innovation ecosystem would benefit from streamlining the activities of the various IP agencies, developing technical capacity and creating more awareness of the value of IP.

Business support

Innovation and business support services in Kenya revolve around various organizations and government programmes that support innovative enterprise creation and growth. One such programme is Export Processing Zones (EPZ), which offer manufacturing firms incentives and low-barrier environments to access export markets and foreign direct investment opportunities. Businesses also receive support through various incubation programmes across the country that offer entrepreneurship capability training and co-working spaces. The most prominent are the ICT hubs that support and commercialize software. Examples include the iHub, university-affiliated labs such as Nailab, and state-run incubator programmes like the Technology Business Incubator run by the Kenya Industrial Research and Development Institute.

To facilitate technology transfer and stimulate the emergence and growth of technology-based firms and industries, the government is also focused on establishing STI parks. The first mega project – entitled Konza Techno City and nicknamed 'the Silicon Savannah' – is a 20-year, 2,000-ha, US$14.5 billion new town project due to be completed in 2019. Universities such as the Jomo Kenyatta University of Agriculture and Technology (JKUAT), Maseno University and the Multimedia University (MMU) have also established SME-focused or sector-specific technology parks.

Beyond these targeted policy instruments, the Ministry of Industry, Trade and Cooperatives (MITC) launched a more comprehensive strategy in 2017 to create an enabling environment that bolsters the production and consumption of locally produced goods and services, named 'The Buy Kenya - Build Kenya Strategy'. Strategies include stimulating local public procurement by reserving 40% of the public procurement budget for locally produced goods and services, providing subsidies and incentives for local producers, raising quality standards, increasing investment in industrial R&D and technology transfer, and advocacy for sustainability-related activities.

Financial resources

Public funds have been a pivotal source for scientific research, inventions and innovations, previously administered by the then National Council for Science and Technology, and now managed by the National Research Fund (GoK, 2014*b*). Between 2008 and 2016, the Fund grew from US$3.3 million to US$5 million and has financed 1,816 scientific and policy research projects and technological and social innovation projects in over 100 institutions across the country.[9] In contribution to the national gross domestic expenditure on research and development (GERD) indicator, Kenya has committed to allocate 2% of the country's GDP every year in addition to any funds received from external sources as donations, endowment or grants. However, in 2007, the GERD, which encompasses both public and private investment in R&D, only amounted to 0.36% of GDP, rising to 0.79% in 2010 (UNESCO, 2016). Kenya has, however, almost reached the African Union's recommended R&D spending of 1% (Hanlin, 2017).

9 National Research Fund background, http://www.researchfund.go.ke/?page_id=10, accessed 29 September 2017, (GoK, 2014*b*)

Apart from the national treasury, STI funding within the innovation system is raised independently by institutions of higher learning which, in 2010, accounted for approximately 39.05% of GERD. Most of these funds are raised from independent bids for research grants from international multilateral organizations such as the European Union, IDRC, DFID, DANIDA and the World Bank. Additionally, multinational corporations such as Google, Nokia and IBM are increasingly investing in university-led research and development projects. Research spending by Kenyan firms, however, remains low at just 0.5% of revenues, with the vast majority spent on internal R&D programmes.

In general, funding levels for R&D in Kenya are difficult to track and aggregate. Data from the Ministry of Higher Education, Science and Technology, however, indicate that almost half of R&D funds originate from foreign sources, 19% from higher education institutions, 17.5% from government and a meagre 4.4% from business enterprises, as **Figure 4.5** illustrates. The government's contribution may be higher, given that public universities may allocate funds acquired from government to research. Additionally, of all money spent on R&D in 2010, almost half went toward agricultural sciences, while 28% went to medical and health sciences.[10]

Figure 4.5. R&D expenditure in Kenya by source.
Source: GoK 2014.

4.6. Knowledge systems in Kenya

Kenya has diverse knowledge systems that have implications for the forms of research and education for sustainable development, and for the capacity to generate context-relevant knowledge that could effectively address local sustainability challenges. Below, we outline the main aspects of these knowledge and educational systems.

4.6.1. The scientific knowledge system

We consider the education system and the formal research system as constituent parts of the scientific knowledge system. From 2018, Kenya will transition from an 8-4-4 system of education implemented in 1985, i.e. 8 years at primary school level, 4 years at secondary level and 4 years at tertiary level, to a 'competency-based approach' (CBA) aligned to international best practices (Kabita and Ji, 2017). The CBE curriculum is based on a 2-6-6-3 structure: 2 years of pre-primary, 6 years of primary and 6 years of secondary education, where learners will specialize in one of three tracks: arts and sports science; social sciences; and science, technology, engineering and mathematics (STEM). Post-secondary education will depend on the type of qualification pursued, with university education pegged at a minimum of 3 years. The new curriculum is expected to improve the long-term capacity of the formal knowledge system in Kenya.

Photo 4.4. Science centre on Wasini Island (Kenya)
© UNESCO/J. Chaves-Chaparro

Nevertheless, to date, student enrolment rates and the number of educational institutions at all levels within the 8-4-4 system have steadily increased in number and expanded in size. Primary school enrolment dramatically increased in 2003 upon the implementation of free primary education, which contributed towards achieving MDG 2 on Universal Primary Education. Unfortunately, student enrolment growth rates are dampened by a high dropout rate during and after primary education, and after secondary school due to insufficient financial resources for enrolment at the next level.

The government of Kenya responded to this gap by devoting the largest share of its recurrent budget – up to 21% of

national revenue and 6.7% of GDP in 2012[11] – to expanding education, particularly at the primary and secondary school level. Improvement in gender equality at primary school is also apparent, from a gender parity index (i.e. ratio of girls to boys) of 0.733 in 1970 to 0.995 in 2015.

Higher education in Kenya has seen a dramatic expansion in recent times. Data from the 2016 Kenya Education Sector Report shows that since 2000, university-level enrolment has increased rapidly from 49,000 to 480,000 students, as the number of institutions of higher learning expanded from 19 to 70. University enrolment growth, however, is largely driven by undergraduate enrolment, with master and doctoral levels lagging significantly. Despite these expansions, the capacity of the higher education sector remains limited, as only 3% of the university-aged cohort is enrolled in universities. On the other hand, vocational training via technical vocational education and training (TVET) institutions is gradually expanding with increased investment from the government. The number of public TVET institutions rose from 571 in 2014 to 874 in 2016, with enrolment increasing from 55,945 to 100,862 respectively. TVET has traditionally been viewed as a last-resort career trajectory that has negatively influenced the much-needed supply of technical and vocational skills in the market. To popularize TVET enrolment, the government has developed outreach programmes, TVET fairs and Technology competitions, such as robot contests and the African TechChallenge.

Available data shows that in terms of disciplinary focus, 25.5% of university students enrol in social sciences, including business and law programmes, followed by education at 20.39% and engineering, manufacturing and construction programmes at 17.4.[12] Cumulative participation in programmes related to STEM remains low at just 22%. University training programmes are set up in traditional disciplinary silos, and while there are efforts to expose students to a variety of subjects during their undergraduate programmes, efforts to deliberately implement multidisciplinary programmes are isolated. Postgraduate programmes, on the other hand, offer better spaces for interdisciplinary approaches to tackling scientific and practical challenges.

The education sector in Kenya faces challenges such as inadequate funding for programmes and inadequate staffing. Increased student enrolment at all levels has also strained available infrastructure and resources. There is low engagement between academic and business communities in curriculum development, and this contributes to the mismatch between skills acquired in school and industry needs. Gender disparities persist in higher education, particularly in tertiary education where 30% more male students are enrolled.

Scientific or 'formal' research in Kenya is carried out in universities and TVET institutions, public research institutes, the private and not-for-profit sectors. In general, research and development staffing levels and output have been rising quickly, albeit from a small base. Between 2007 and 2010, the number of research and development personnel in Kenya grew eightfold. The participation levels of women doubled during that period. Although institutions of higher learning employ 60% of research staff in the system, business enterprises and non-profit organizations are increasingly employing R&D staff.

Like the R&D indicators, Kenya's share of publications in international peer-reviewed journals is also increasing, but from a small base. Kenya ranks sixth in Africa behind South Africa and Nigeria in terms of volume of articles. Nevertheless, the quality of publications relative to other African countries is relatively better, ranking second after South Africa according to the average H-index of Kenya's publications and ranking first according to the average of citations per document (see **Table 4.2**). The University of Nairobi is the most prolific institution in producing peer-reviewed articles. Public and private research institutes have also been generating a significant level of scientific research, as shown in **Table 4.3**. Disciplines with high volumes of publication include biological sciences, agriculture, medicine, social science and environmental science respectively, and this distribution has been largely stable between 1996 and 2014. The levels of international collaboration are high, in that 80% of published articles are produced with external scholars, in particular from the United States, South Africa, Canada, United Kingdom, and neighbouring countries Uganda and Tanzania.

11 World Bank data, 2012

12 UNESCO Institute for Statistics, 2017

Table 4.2. Scientific publications, citations and rankings.

Country	Documents	FTE researchers per million inhabitants (2013)	GERD as % GDP (2010)	Citable documents	Citations per document	H index	Africa ranking
South Africa	188 104	408	0.76	172 424	11.30	320	1
Nigeria	59 372	39 (2009)	-	56 630	5.63	131	2
Tunisia	58 769	1 394	0.69	55 904	5.83	123	3
Algeria	42 456	165 (2009)	-	41 544	5.09	106	4
Morocco	40 737	864	0.71	38 371	6.87	129	5
Kenya	24 458	227	0.98	22 347	15.52	179	6
Ethiopia	13 363	45	0.24	12 625	8.88	101	7
Tanzania	11 964	36	0.38	11 140	14.22	122	8
Ghana	11 543	39	0.38	10 578	9.63	105	9
Uganda	11 528	37	0.50	10 599	14.87	128	10

Source: UNESCO Institute for Statistics (UIS), 2017 data.

Table 4.3. Ranking of research institutes in Kenya according to their web publications

Ranking	World rank	Institute	Size[1]	Visibility	Rich files[2]	Scholar[3]
1	281	World Agroforestry Centre	648	461	455	362
2	1 002	African Wildlife Foundation	1 688	304	3 079	2 692
3	2 248	Kenya Agricultural and Livestock Research Organization	2 131	5 576	2 804	466
4	2 368	African Agricultural Technology Foundation	3 455	2 849	2 652	1 966
5	2 804	African Population and Health Research Centre	1 339	3 047	3 692	3 089
6	3 092	International Centre of Insect Physiology and Ecology	2 061	2 314	2 003	4 315
7	3 212	Kenya Medical Research Institute	256	3 224	4 533	4 011
8	3 269	African Medical Research Foundation	2 952	1 253	5 199	4 911
9	3 844	Kenya Institute for Public Policy Research and Analysis	3 174	3 063	5 481	4 011
10	3 936	Climate Prediction and Applications Centre, Kenya	3 550	4 515	3 188	3 420
11	4 487	African Academy of Sciences	4 823	3 092	4 849	4 911
12	4 539	Welcome Trust Research Laboratories, Nairobi	2 713	3 595	5 538	4 911
13	5 563	Kenya Marine and Fisheries Research Institute	6 233	5 046	6 081	4 315
14	5 751	Mpala Research Centre	6 586	5 128	5 155	4 911
15	6 534	Tea Research Foundation of Kenya	5 243	6 349	6 554	4 911
16	6 673	US Army Medical Research Unit, Kenya	7 028	6 071	6 853	4 911
17	7 195	African Conservation Centre	6 561	7 140	5 867	4 911

[1] Size: number of pages recovered from Google, Yahoo, Live search and Exalead;
[2] Rich files: volume of documents according to their relevance to academic and publication activities;
[3] Scholar: number of papers, reports and other academic items from Google Scholar.
Source: Scimago Lab, 2016. Data by Scopus, www.scimagoir.com

Patenting as a way of protecting and appropriating benefits from invention or innovation in Kenya has historically remained low, peaking at 295 applications in 2013 – a fact that supports the debate to strengthen the intellectual property rights framework and create awareness, as discussed in section 5.2.1. WIPO statistics[13] show that the three top patenting fields between 2001 and 2015 are pharmaceuticals (13.5%), handling (11%) and basic materials chemistry (9%). Trademark applications, on the other hand, are significantly higher in 2015, at 6,690. **Table 4.4** and **Table 4.5** summarize the main intellectual property indicators.

The formal knowledge system in Kenya suffers a high rate of 'brain drain', i.e. attrition of students, professionals and academic research staff. This has been attributed to the lack of support and recognition, poor infrastructure for researchers and relatively low remuneration. However, the outbound mobility ratio has been dropping gradually as new opportunities are

Table 4.4. Main IP indicators for Kenya

Year	IP filings (resident - abroad)			Patent applications			Patents granted			Utility models applications	
	Patents	Trademark	Industrial designs	Resident	Non-resident	Abroad	Resident	Non-resident	Abroad	Resident	Non-resident
2007	52		42	41	91	11	4	13	1	16	
2008	67		39	63	89	4	5	37	6	18	1
2009	56		76	48	123	8	6	81	9	29	1
2010	81		69	77	120	4	4	50	2	28	
2011	160		87	135	122	25	4	55	4	51	
2012	143		94	123	136	20	4	72	2	68	
2013	181		80	127	114	54	1	70	7	78	
2014	160		79	132	75	28	4	49	26	83	
2015	179	5 670	75	137	56	42	1	23	24	114	1
2016	202		89	144	59	58	5	21	3	136	

Source: WIPO Statistics, last updated March 2018.

Table 4.5. Main IP indicators for Kenya

Year	Number of designs in industrial design applications			Number of designs in industrial design registrations			International applications via WIPO-administered treaties			PCT National Phase Entry (direct and via regional office)		
	Resident	Non-resident	Abroad	Resident	Non-resident	Abroad	PCT	Madrid	Hague	Resident	Non-resident	Abroad
2007	42	32		16	19		2	2			85	4
2008	39	10		33	15		5	2			89	
2009	76	14		90	13		4	10			117	2
2010	69	7		39	11		9	7			118	
2011	86	28	1	31	9	1	4	3			121	14
2012	93	10	1	38	12		7	2			128	8
2013	78	8	2	30	8		9	5	1		111	42
2014	78	17	1	31	3		11	6			75	6
2015	73	12	2	52	5		4	11			52	19
2016	89	15		38	125						56	32

Source: WIPO Statistics, last updated March 2018 (PCT top applicants: International Centre of Insect Physiology and Ecology; FUTUREPUMP Ltd.)

13 WIPO Statistical Country Profiles: Kenya. http://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=KE

created in expanding universities with increasing funds, and new opportunities for R&D staff in the private sector open up.

4.6.2. The indigenous knowledge system

Due to the diversity of its ethnic communities, Kenya has a rich cultural heritage with vast indigenous resources and knowledge, among them traditional literature, arts and crafts, music, visual arts, ceremonies, traditional architecture, forms of traditional knowledge related to medicine and related practices, agriculture, forest management and conservation, and sustainable use of biological diversity. These knowledges and resources are categorized into three closely intertwined themes: traditional knowledge, genetic resources and traditional cultural expressions or folklore.

In contrast to formal scientific knowledge that is easily codifiable, indigenous knowledge is preserved and transmitted via tacit means such as repeated practice, apprenticeship and oral tradition. Common cultural expressions include sayings, proverbs and metaphors. Further, indigenous knowledge is dynamic and holistic, and in many cases contains cultural or spiritual value that is difficult to codify, quantify and monetize. Communities use their own locally-specific systems of classifying types of knowledge, acquiring and sharing knowledge with inherent rights and responsibilities. For instance, the Maasai community possess traditional rangeland classification systems that were found useful in assessing indicator species suitable for livestock grazing (Oba, 2001). These systems are not captured by existing legal frameworks for intellectual property protection and, as a consequence, have been open to exploitation by other actors who derive innovations from these knowledges and receive economic benefits that exclude the indigenous custodians.

There is increasing recognition of the importance of indigenous knowledge as a potentially important contributor to a more sustainable trajectory of mainstream development. In agriculture for instance, traditional communities have innovative soil fertility, intercropping, weed control, water and anti-desertification

Photo 4.5. Kenyan maasai rangeland traditional classification systems used in assessing indicator species suitable for livestock grazing

practices that would add value to the management of agro systems (Njoroge, 2017). Rural communities have developed elements of disaster preparedness and agro-technical strategies to deal with recurrent drought and famine which could inform innovation on food security (Akong'a and Kareithi, 1998). Similarly, the Maasai's ecological knowledge, when integrated in biodiversity management, could enhance sustainable natural resource planning. This realization is demonstrated in the increase in research into indigenous knowledge systems in Kenya. In their bibliographic analysis, Kwanya and Kiplang'at (2016) find that of the themes researched, agriculture was the most popular at 26% of articles reviewed, followed by health (14%), ecology (10%), environment (9%), development (7%) and climate change (6%). It is evident that there is interest in exploring indigenous knowledge for insights on themes related to livelihoods and sustainability.

So far, Kenya appears to have institutional will at the national level to invest in efforts to safeguard and develop indigenous knowledge. National publication trends analyzed by Kwanya and Kiplang in 2016, showed a big increase in the number of research papers on indigenous knowledge, from 45 papers between 1986-1991 to almost 300 between 2010-2015. Kenya is one of nine countries in Africa that adopted the Swakopmund Protocol on the Protection of Traditional Knowledge and Expressions of Folklore in 2010, which provides a framework that would protect traditional knowledge-holders against misappropriation, misuse and unlawful exploitation beyond their traditional context. Further, various research organizations, government and private sector initiatives have taken steps to identify, recognize, validate, codify and store indigenous knowledge, and mobilize such knowledge to develop solutions to pressing sustainability problems.

A prominent example is the Ministry of Higher Education, Science and Technology initiative to begin mapping and documenting indigenous knowledge capacity among various communities, cultures and tribes of Kenya. One expected outcome of the study is an evaluation of the contribution of such knowledge to the economy within the paradigm of Vision 2030. In 2009, the National Policy on Traditional Knowledge, Genetic Resources and Traditional Cultural Expressions was developed to mobilize indigenous knowledge to accelerate technological development, respond to the integration of economic, ecological, cultural, trading and information systems, and address intellectual property rights.

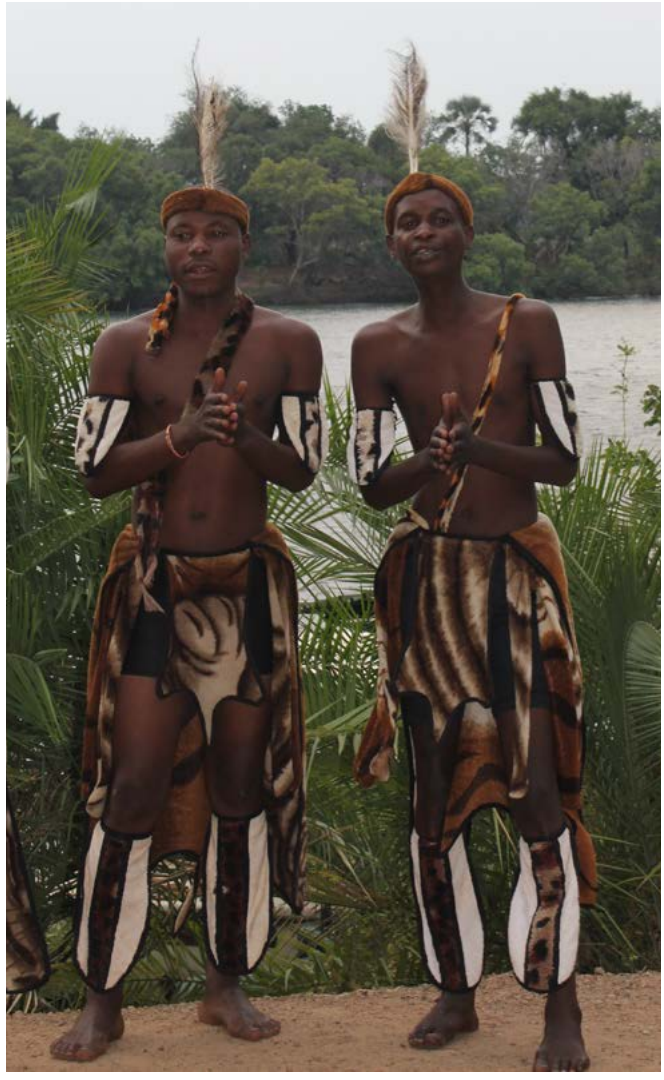

Photo 4.6. Traditional folklore is an touristic attraction and economic source of living for Indigenous peoples in the Victoria falls park (Zimbabwe)
© UNESCO/J. Chaves-Chaparro

4.6.3. Cooperation among knowledge systems

An endogenous approach to sustainable development calls for 'locally defined models of sustainability in which will prevail the realities of local peoples, with all their societal, cultural, political, spiritual, moral, and ecological goals and aspirations' (Dei, 2002, p. 12). These models of sustainability can be collaboratively developed through mechanisms that foster interactions across existing knowledge systems. Various interactions could be envisioned: across industry systems, between businesses,

universities and research institutions, and between formal or 'Western' science and indigenous knowledge systems, and even between different locally-specific indigenous knowledge systems. Below, we explore the extent of these interactions in Kenya.

University-industry cooperation

Available data show that linkages between knowledge-based institutions, including universities and public research institutes in Kenya and the business community, have historically been weak. To a large extent, universities' connection with the private sector has for a long time been through the training of manpower that would be eventually absorbed into businesses. Even then, systematic collaboration between academia and industry in curriculum development is also lacking. Additionally, research activities in universities that are conducted with the view of direct commercialization or generating knowledge spillovers into the private sector have only happened on a small scale. Consequently, novel ideas developed in universities largely remain unexploited or frozen in academic publications. Similarly, public research institutes have yet to unleash the full extent of their capabilities to support innovative activities in the industry.

The business community, on the other hand, has expressed relatively low interest in engaging with academic institutions in their innovative processes, as illustrated in **Figure 4.8**. Only 38% of businesses source for information from universities, and 40% from public research institutions. The level of collaboration between companies and these organizations is, however, slightly higher, at 46% with universities, and 41% with public research institutes. Companies seem to find information from scientific journals more useful for their R&D activities, with up to 65% using it. More businesses also source for information from conferences and trade fairs (71%), and professional and industry associations (72%). Relatively speaking, it is apparent that businesses rely heavily on internal sources for information (96%), and also opt to source for information more from the market, particularly their suppliers, customers, competitors and consultants, commercial labs or private R&D institutes. They also cooperate more with these actors in their innovative activities, and even more so with customers. This scenario indicates that there may be incongruence in the innovative efforts of research institutions that render innovation outputs inapplicable for the industry. Alternatively, platforms that should enable knowledge sharing across these actors, such as innovation intermediaries, are inefficient or lacking in the innovation system. This trend also indicates that there is inefficient use of public research funds intended to stimulate an innovative ecosystem through basic and applied research.

Nevertheless, there are increasing ad hoc efforts to create joint projects between universities and industry that indicate that these actors are now finding it mutually beneficial to collaborate. One such intervention is the industry-led partnership with the government, Linking Industry with Academia (LIWA). LIWA established 15 partnerships between Kenyan universities and major industry players, such as Huawei and Safaricom, to improve the quality of graduates by updating curricula, training innovators and offering internship programmes. In addition, businesses are progressively adopting open innovation strategies to better access and integrate external sources of knowledge, leading to a stronger interest in collaboration with universities. Further, the strategic mission of universities has moved beyond the tradition of teaching and research toward a 'third mission' related to better addressing the needs of industry and contributing directly to economic growth and development (Bolo, Odongo and Awino, 2015).

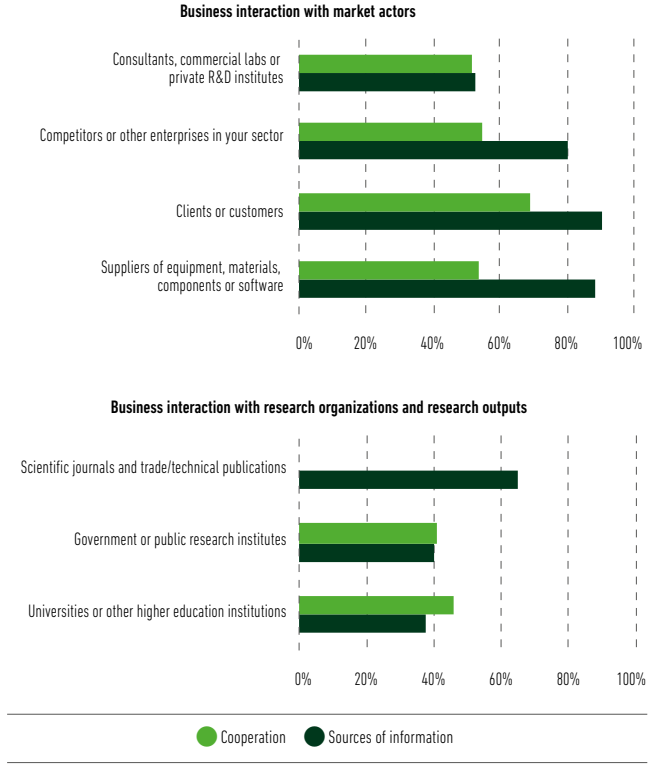

Figure 4.6. The use of university-generated knowledge in business-level innovation processes.
Source: Compiled from data from UNESCO Institute for Statistics, 2017

The benefits of strengthening university-industry linkages for sustainable development in Kenya could be wide-reaching, and they include: 1) coordination of R&D agendas and avoidance of duplication, 2) stimulation of additional private R&D investment,

and 3) exploitation of synergies and complementarities of scientific and technological capabilities. University-industry collaboration can further expand the relevance of research carried out in public institutions, foster the commercialization of public R&D outcomes, and increase the mobility of labour between public and private sectors.

Inter-university collaboration

The rising sustainability concern in Kenya is making a new capacity-building demand on universities, which may have a far-reaching impact, not only in altering the structure and functioning of these universities, but also in enhancing their relevance and usefulness to society. In recognition of this, the 2008 STI Policy aimed to 'encourage and support collaborative, multi-disciplinary scientific research in universities and other academic, scientific and engineering institutions'. While there is progress in this area, several challenges at the personal, institutional and policy level have dampened inter-university collaboration.

Based on the findings in a 2007 report by the Kenyan National Strategy for University Education Task Force, it is apparent that Kenyan universities have for a long time been developing partnerships with both local and foreign universities. Partnerships with foreign universities have yielded funding for collaborative projects, joint masters and Ph.D. programmes, and faculty and student exchange programmes. Examples include joint degrees in engineering sciences between Egerton University and Western Michigan University in the USA, and collaborative research on educational technology between the University of Nairobi and Concordia University, supported by a seven-year grant of Can$2.5 million from the Social Sciences and Humanities Research Council (SSHRC), Canada. By analysing a joint urban study between the University of Nairobi and Columbia University, Klopp et al. (2014, p. 222) show that these types of collaborations provide rich experiences for students and can be important for teaching cross-cultural skills, respect for local learning and knowledge, and advocate for 'transformational' and 'authentic' partnerships.

Regionally speaking, Kenya is also a member of the Inter-University Council of East Africa (IUCEA) and the Association of African Universities (AAU), which support joint projects and faculty and student exchanges. The IUCEA has, for instance, supported the Lake Victoria Environment Initiative regional network. A study on this initiative, however, shows a need for improvement in these types of networks where weak linkages and information gaps among collaborating researchers and research institutions exist, women's participation is low, and bureaucracy and institutional inefficiency undermine their effectiveness (Okaka, Migunga, Ngaira and Mbego, 2016).

However, evidence of collaboration among Kenyan universities is scarce, with available information limited to initiatives driven by the government and non-university actors. Various infrastructural and support initiatives are being put in place to enhance knowledge sharing among universities in Kenya. One such initiative is the government-subsidized national broadband network, the Kenya Education Network (KENET), which was set up in 1999 and serves as the national research and education network. KENET facilitates the sharing of educational and research resources and the joint production of online teaching materials. For the 2017/2018 financial year, the National Research Fund has advertised a multidisciplinary research grant programme, in which project proposals must include collaboration between three research institutions. The Kenya Open Data initiative, launched by the Ministry of Information and Communication (MOIC), was established *inter alia* to facilitate knowledge sharing among research institutions.

Apart from institutional-level partnerships, collaboration among scholars in Kenyan universities has also been increasing, albeit in a limited fashion. In an extensive study of university researchers in Kenya, Muriithi et al. (2018) find that about two-thirds of university-based researchers are involved in collaborative research, but this varies by disciplinary area. However, scholarly collaboration and research productivity are constrained by limited access to research funding and facilities, a strong emphasis on teaching relative to research in Kenyan universities, competition for resources among local universities, weak links with industry, high levels of bureaucracy, and inadequate policies.

Dialogue between Western science and indigenous knowledge

There is much debate in the academic literature on the complexities of integrating traditional or indigenous knowledge systems embedded in the culture, traditions, ideology, language and religions of local communities with Western science, and whether the binary tension between these knowledge systems exists in reality (Briggs, 2005; Ocholla, 2007). Nevertheless, researchers agree that indigenous knowledge offers a basis for further breakthroughs in industrialization that are in harmony with the environment (Njoroge, 2017). The Kenyan Government, however, acknowledges that there has been a marginalization of local technologies and local systems of knowledge in formal policy-making and the educational system. The lack of clear and enforceable mechanisms to manage research on indigenous

knowledge and foster consultation or collaboration with local communities has also stunted the engagement between Western scientific approaches and indigenous knowledge systems.

Upon independence, the Kenyan Government made efforts to integrate indigenous knowledge into the formal education curriculum in a bid to moderate the power, prestige and authority of Western knowledge and leverage the potential of indigenous knowledge for sustainable development (Owuor, 2008). Today, the education system still privileges Western knowledge, and more interventions through curriculum reforms and teacher re-education are needed to promote traditional knowledge in schools. Fortunately, academic researchers in tertiary institutions are increasingly engaging in research on indigenous knowledge in different fields (see section 5.4.2). However, these efforts are isolated and more systematic support by universities, and collaboration between universities and schools, is needed in order to scale them up.

On a grander scale, there is a more deliberate effort by government agencies to integrate indigenous forms of knowledge into formal knowledge systems in Kenya. The Ministry of Health has invested considerable resources to foster the use of indigenous knowledge in primary healthcare, particularly through community health workers who link the community to the formal healthcare system. Similarly, the Kenya Forestry Research Institute (KEFRI), which recognizes that the majority of Kenyans in rural areas depend on medicinal plants for treating various ailments, now generates and disseminates technologies that promote conservation, utilization and domestication of medicinal plants, and is investing in capacity-building among herbalists in the conservation of specific plant species. KEFRI also documents indigenous traditional knowledge on medicinal plants.[14] The National Museum of Kenya invests in collecting, documenting and disseminating Kenya's cultural heritage to enhance the codified knowledge base.

Until now, there has been an ad hoc approach towards the research, documentation, protection and development of indigenous knowledge. Efforts to map and preserve indigenous knowledge by the Ministry of Higher Education, Science and Technology will not only contribute to strengthening indigenous knowledge systems, but will provide mechanisms to access such knowledge for academic research and industry innovation through, for instance, appropriate IPR systems under development that would be consistent with those forms of knowledge. The National Policy on Traditional Knowledge, Genetic Resources and Traditional Cultural Expressions (2009) further provides an operational framework for stimulating ethical exploitation of indigenous knowledge in the scientific system. In a bid to mainstream interactions between research and technological innovation and indigenous knowledge and technologies, a flagship project of Vision 2030 – the Natural Products Industry initiative – aims to stimulate a natural products industry including medicines, food additives, cosmetics and veterinary products. Programmes under this initiative aim to commercialize intellectual property extracted from such interactions by manufacturing niche products for local and global markets. The Kenya Community Development Foundation (KCDF), which is a public philanthropic foundation, is also investing in community-led initiatives by mobilizing resources, building capacity, building partnerships and influencing policy on behalf of communities. These new approaches will recognize the often-downplayed role of women in sustaining indigenous resources.

While there is little documented evidence of the absorption of indigenous knowledge into the 'formal' knowledge system, empirical research has shown that communities at the grassroots level routinely appropriate elements of formal science that they see as advantageous to their economic, social and political circumstances (Briggs, 2005). The challenge, therefore, is largely on the part of policy to mitigate the marginalization of indigenous knowledge within the formal innovation system, particularly among scientists and industry practitioners. A pluralistic approach to knowledge systems in which all stakeholders respect and acknowledge the value of diverse knowledge systems, embrace their logic and epistemological foundations, and identify their reciprocal relations, is advocated as a critical pathway to address social, economic and environmental sustainability challenges in Kenya (Mwenda, 2003; Owuor, 2008; Semali, 1999).

4.7. Success stories of collaborative interdisciplinary research and innovation

The above discussion on Kenya's sustainability, systems facing sustainability challenges and the current role of research and innovation, is a reflection of the varied, ongoing attempts to promote sustainable development. The following section presents three such attempts, which combine transboundary innovations along multiple dimensions. The three cases are evidence that interdisciplinary research and innovative initiatives will continue to take centre stage in addressing sustainability problems in Kenya.

14 Kenya Forestry Research Institute, 2013

4.7.1. Case 1: Frugal innovation in weather prediction: the TAHMO initiative

(This case was compiled from primary interviews conducted by the authors with the TAHMO Chief Executive Officer and one of the founders and co-directors of TAHMO)

Sub-Saharan Africa has historically suffered from unreliable weather prediction services. This challenge arises from the fact that the continent has the smallest number of hydrological and meteorological stations per square kilometre and, as a consequence, localized ground-based real-time data is unavailable. To address this gap, a non-governmental organization – the Trans-African Hydro-Meteorological Observatory (TAHMO) – is working together with national meteorological agencies to install a network of 20,000 frugal automatic weather stations across sub-Saharan Africa. In Kenya, TAHMO has so far installed 100 weather stations.

TAHMO's intervention in weather prediction has three dimensions. The first dimension focuses on frugal innovation to design reliable, low-cost, robust weather stations that require little maintenance, taking into account the shortage of relevant technical skills in rural areas. The second dimension focuses on water and climate education. TAHMO stations are installed in secondary schools – an approach that provides reciprocal benefits. On the one hand, schools have an opportunity to collect data from the stations and access learning materials for their science and geography curriculum; on the other hand, TAHMO can access a safe and conducive environment that protects and maintains the stations. The third dimension focuses on the financial sustainability of the initiative by exploring opportunities to monetize weather data, while offering the same data free of charge to government agencies and research institutions. In this regard, TAHMO is developing different governmental partnerships and business models, among them public-private partnerships with meteorological agencies to develop climate and weather products, and crop insurance through such programmes as Kilimo Salama in Kenya, which insures 100,000 farmers based on TAHMO weather data.

Transdisciplinarity: In Kenya, TAHMO has leveraged transdisciplinarity by entering into partnerships with two universities based on their disciplinary excellence: Strathmore University's iLabAfrica Incubation Hub and the University of Nairobi's Department of Meteorology. TAHMO's collaboration with Strathmore's iLabAfrica explores potential business models that could generate value from the real-time weather databases. Software engineers at the innovation hub are experimenting with mobile applications that package and add value to weather data, and deliver it to interested consumers such as insurance companies, farmers, and actors in the energy and transport sectors. The collaboration with the University of Nairobi, on the other hand, explores the technical aspects of improving the quality of weather data collected from weather stations, calibrating the data based on historical weather information, and exploring further innovations in weather models.

Co-production of knowledge: TAHMO collaborates with the Ministry of Education and secondary school teachers to develop study materials in science and geography that align with the local context. Teachers are encouraged to enter small competitions to draft lesson plans, based on the materials developed, which could be used by other schools within the country and beyond. These materials are made available on the TAHMO website for other teachers to access. In addition, TAHMO has established a School2School programme which offers an online platform for students from over 100 schools across sub-Saharan Africa to learn about water and climate change, and to share their knowledge with their peers (www.school2school.net). The platform further pairs schools in relationships known as 'sister-schools' to facilitate more intensive knowledge sharing.

By adopting a collaborative approach and frugal innovation to address weather prediction gaps, the TAHMO initiative, when scaled up, will have a positive impact on sustainability through optimizing the management of natural resources by many actors, and developing context-relevant educational and scientific knowledge on climate change.

4.7.2. Case 2: Education for Sustainable Development in Africa (ESDA) programme

Compiled from Nagao and Mutisya (2015)

Research on Kenyan and African development confirms the complexity of sustainable development issues and points to the general need for solid, context-based empirical work in order to improve understanding of the phenomenon involved, as well as to inform policy and practice. Research on sustainable development calls for scholars to play an active role. This is because a long-term horizon is needed for the burgeoning research on sustainable development and, in particular, to establish a robust empirical foundation. These scholars should demonstrate a greater readiness and willingness, as well as the resilience required by the physically demanding conditions of field-based research.

Kenya's higher education curriculum is exam-oriented and is lacking in practical orientation. This is because universities in Kenya, as in many African countries, have set their curricula to focus principally on individual excellence; the main priority being the passing of examinations, with little or no emphasis on practical skills. Kenya's universities therefore face the risk of dropping out of knowledge-based society. According to Eshiwani (1999), contemporary Kenyan universities should put more emphasis on research and make a deliberate effort to facilitate training, engage in research and disseminate findings in a way that connects school knowledge to practical issues affecting society. In meeting this enormous challenge, Kenyan universities have a particularly important role to play as the intellectual infrastructure of the continent.

Transdisciplinarity: Against this backdrop, Kenyan universities, together with other African universities, have been working since October 2008 to develop a joint postgraduate programme to shape a new generation of professionals for Africa's sustainable development. This development work, initiated by African universities and seed-funded by the Japanese government, is now complete and the African partner universities have launched three master's programmes – 'Sustainable Integrated Rural Development', 'Sustainable Urban Development' and 'Mining and Mineral Resources' – enveloped together as 'Education for Sustainable Development in Africa (ESDA)'. The ESDA is a proactive collaboration strategy by Kenyan and African universities, in partnership with the United Nations University and Japanese universities, for inter-university and transdisciplinary collaboration. These programmes not only combine the curricular and didactic strengths of the participating universities for synergy effect but also promote interactions with all the relevant stakeholders of the development process, including community, industry and government, through the adoption of field-based, problem-solving approaches 'on site'. With the field-based and problem-solving approach needed to support sustainable development in Africa, the programme aims to generate a new breed of African professionals who will work for greater social relevance and towards creating a lasting impact on the developmental reality of Africa.

As such, the ESDA programmes offer a unique and innovative opportunity for professional development to mid-career development agents needing to upgrade specific skills, as well as to first degree finishers aspiring to pursue a career in sustainable development. Once fully established, the programmes will serve as a vehicle for capacity generation to sustain the structural transformation of African countries, including building up the private sector and strengthening governance mechanisms.

Co-production of knowledge: Although Kenya is participating in all three programmes, Kenyan universities developed the curriculum for the Sustainable Urban Development (SUD) programme. This was led by the University of Nairobi and Kenyatta University, in collaboration with the United Nations University, UNEP and UN-HABITAT, among other stakeholders, for knowledge co-creation, co-production and sharing. SUD is now training a number of students, providing them with sustainability knowledge and skills in line with the development needs of the country. The education, research and practice components of the programmes, delivered within the collaborative framework, are further promoting programme excellence (quality education and research) as well as high impact (practice) to stakeholders and community development. This provides answers to the collaboration weakness in Kenya's research and innovation institutions, and the ESDA programmes are thus expected to enhance the critical role of universities for sustainable development in Kenya.

The training of the younger generation to lead sustainability initiatives reflects multiple lines of innovative thinking for the ESDA programme. On the one hand, it aims to satisfy the long-term needs of Kenya's sustainable development. On the other, it helps to ensure partnership equality between Kenyan researchers and institutions. As of 2017, the programme has enrolled and trained 175 graduates, with all the graduates having either secured job opportunities in various sectors of development or further study opportunities. ESDA remains one of the major home-grown sustainability programmes in Kenya, and continues to address human needs for Kenya's development.

4.7.3. Case 3: Organic agriculture with trees (OAT)

Compiled from Ngetich et al. (2010)

This project focused on the potential of strategic ecological farming practices (organic farming, agroforestry and forestry) to stabilize the East Mau water catchment in Kenya, thereby contributing to improved livelihoods, sustainable use of resources, self-sufficiency, and a market surplus of catchment products, as well as to environmental conservation. The project was divided into three distinct work packages (WPs):

1. The farming systems WP evaluated the potential of sustainable land use for the whole catchment, including how to re-establish organic farming practices in areas facing environmental problems.

2. The marketing WP developed a model for linking organic key catchment products to the market, incorporating an analysis of the national demand for organic products.
3. The social systems WP investigated farmers' perception and attitudes, decision making in smallholder timber farming, woody plant resources in rural land use, and the motivation for and acceptance of organic initiatives; it also sought to characterize information systems, linking local knowledge and decision making.

To adequately and comprehensively cover the above WPs, a transdisciplinary research approach, based on several disciplinary perspectives and input from local stakeholders, was adapted. The research team comprised scientists from the following disciplines: animal science, agronomy, agricultural economics and sociology. Students participating in the project also came from diverse disciplinary backgrounds.

The project also integrated ethnically diverse groups of people, in order to ensure that a broad spectrum of lifestyles was represented. Taking ethnic diversity into account enabled the study to access local knowledge systems that are unique and diverse. The research approach employed transdisciplinarity/co-design, as opposed to conventional 'participatory' approaches, by ensuring a diversity of people throughout the process. All workshops were participatory in nature. They were organized so that facilitators were drawn from the scientific team, as well as the local farmers and non-governmental (NGO) representatives. While appreciating the many forms and meanings of participation, this meant that in this project, stakeholders were part of the research process and influenced the research focus as well as the interpretation of results in problem solving.

From this case study, the involvement of different disciplines helped to bridge the knowledge gap and enhanced holistic understanding. However, developing a common theoretical framework and methodological understanding was challenging for researchers with different experiences and competencies. It was acknowledged that a basic understanding of qualitative social science can support the development of a common understanding.

In the context of Kenya, and in particular the Mau watershed, the transdisciplinary approach provided a much deeper understanding, due to the multiple perspectives obtained by integrating the views of different stakeholders in the project. It was evident from the project that integrating stakeholders at different phases of the research process yields valuable insights, improves logistics and enhances research output. Furthermore, mainstreaming the integration of stakeholders into the research process is crucial in ensuring that research is relevant to the needs of the people (farmers) as well as policy-makers. The integration of ethnic knowledge brought in hybrid expertise previously often overlooked, due to an excessive compartmentalization of knowledge into 'traditional' and 'modern'. The traditional modern distinction fails to take into account emerging forms of knowledge that pervade African societies. However, the cross-fertilization of knowledge through workshops created an environment which promoted synergy and synthesis in the project.

4.8. Science, technology and innovation policy gaps

Kenya's implementation of the innovation systems approach to STI policy and governance is still in its early stages. Given the complexity of coordinating dynamic sectoral subsystems, numerous actors, institutions and resources, challenges are bound to surface. The challenges below were identified from literature analysis and views collected from participants in a multistakeholder workshop organized by UNESCO and the Kenya National Commission for UNESCO (KNATCOM) from 21–22 November 2016 in Nairobi, Kenya.

Interlinkages between diverse actors and knowledge systems envisioned in the innovation system remain weak and underdeveloped, and effective policy instruments to facilitate exchange are lacking. Public research institutes mandated with this task instead focus on supporting government in public service and conducting independent research. Similarly, professional organizations that should ideally work as knowledge brokers across the system only focus on learning and professional development within traditional boundaries.

Despite the noble intentions of policy-makers in Kenya to address the fragmentation and lack of coordination in the innovation system as a whole, the STI policy framework still fails to explicitly address the dynamics of linking the formal and informal knowledge systems. Efficiency and productivity gains envisioned in Vision 2030 can be pursued by strengthening interlinkages and mutual learning within a more broadly-defined innovation system that consists of a relatively well-developed formal sector and a large, growing and decoupled informal or *jua kali* sector. In essence, this deals with finding mechanisms to *inter alia* enable exchange and interaction between more codified, science-based innovative activity in the formal sector and demand-driven, experiential innovation in the informal sector, leveraging and upgrading technological capabilities in the informal sector, and developing a supportive overall framework.

Photo 4.7. Water Towers project of East Africa
Water level measurement - Water Monitoring Station, Sondu Basin.

STI policy development at the county level is still largely absent, and this is attributed to a lack of technical capacity and financial resources. This weakness is also evident in the lack of region-specific STI policies and programmes that leverage regional capabilities. NACOSTI has a mandate to provide an adequate framework for instruments to revise policy, strengthen technical capacities, develop high-level skills, and improve awareness of STI at county level. While there is rhetoric on the need to mainstream STI within the policy development process across sectors and synergize technology-focused policy interventions, efforts to do so remain fragmented in different ministries. Mechanisms for policy implementation, monitoring and evaluation are also ambiguous. Workshop participants argued that there are no feedback loops to inform stakeholders on the evaluation and revision of policies. A more systematic evaluation process is advocated, in which the Kenyan STI Performance Management Framework should be used after it has been strengthened.

Some participants noted that foreign donors fund most of the research in the country. This implies that the country's research agenda is driven by foreign interests. Additionally, participants perceived that research efforts are not aligned to the country's priorities. The consensus is that the government, with the assistance of NACOSTI and KENIA, should drive the development of an explicit research agenda incorporating societal needs and the voice of the productive sector as one of the economy drivers.

Workshop participants highlighted the mismatch between the existing skills and required skills in Kenya's priority areas. This disconnect is attributed to the haste in expanding university education by upgrading technical institutions to universities, which has affected key areas of employment in the industry. Infrastructural constraints in universities further exacerbate the skill-gap problem. New efforts to strengthen TVET institutions are welcomed to increase the supply of technical skills in the market.

It was widely acknowledged that one of the main driving factors for innovation is the youth. Kenya has many early careers scientists and entrepreneurs with the ability to develop novel ideas and implement them successfully in the market. More targeted policies are required to support the endeavours of youth while leveraging them as a resource in the innovation system.

4.9. Conclusion and recommendations

The adoption of the UN's SDG agenda, the AU's Agenda 2063: The Africa We Want and Kenya's Vision 2030 is challenging knowledge-producing and governance institutions to reassess their role in supporting sustainable development in society. The chapter shows that, while Kenya is faced with many social, economic and environmental sustainability challenges, the country is investing considerable efforts in developing legislation, policies and strategies to address them in different sectors. In addition, the innovation system is gradually mobilizing its knowledge resources to promote new innovation in support of sustainable development in Kenya. These processes are, however, not without institutional challenges.

A key gap is the underdeveloped cooperation within and among existing knowledge systems: across industry systems, between businesses, universities and research institutions,

between formal or 'Western' science and indigenous knowledge systems, and even between different locally-specific indigenous knowledge systems. The chapter identifies instances where cooperation is being fostered through policy instruments and ad hoc projects, and highlights three illustrative case studies in which a co-designed collaborative interdisciplinary approach to research and innovation was adopted: on frugal innovation in weather prediction, education for sustainable development and organic agriculture.

To promote more collaboration between universities and industry in a developing country like Kenya, Guimón (2013) recommends various policy options, among them providing incentives for research projects that bring together consortia of businesses and universities through grants and tax incentives, strengthening the intellectual property rights regime, and creating and supporting technology transfer offices in universities (Bolo et al., 2015; Guimón, 2013). Science parks and incubation hubs are also seen as a potential channel for collaboration, even though tangible evidence of their success is yet to be established.

Pressing sustainability challenges are an opportunity for the higher education sector to redefine its role by prioritizing knowledge for sustainable development. A change in the curriculum to field-based problem solving is important because inherited systems from the North do not fit the current development realities in the region. The new requirements for the curriculum should incorporate multidisciplinary problem-solving approaches, integrate education, research and outreach to tackle sustainable development issues, and contribute to strengthening a resilient society, free from political upheavals (Nagao and Mutisya, 2015). Multi- and interdisciplinarity within research institutions, particularly in universities, can be fostered by initiating cultural changes across the university system by shifting reward systems away from traditional departmental structures. Commonly cited strategies include: incorporating mentoring and interdisciplinary work in promotion and tenure guidelines, supporting marginalized groups, research initiatives that are interdisciplinary and formulating interdisciplinary research seminars, evaluation and advisory committees (Tobi and Kampen, 2017).

As already discussed, fostering cooperation between indigenous knowledge systems and formal science is more complex, due to inherent power dynamics and epistemological differences. Owuor (2008) advocates for the acceptance of multiple knowledge perspectives in the curriculum, the integration of indigenous knowledge, and encouragement of local community inputs in educational processes. Mapping and codifying indigenous knowledge may open up potential opportunities for collaboration with academics and industry practitioners. Beyond these strategies, Gupta (2006) recommends that IPR systems should be reformed to make them accessible to grassroots innovators, that modern information technology applications should be used to overcome information asymmetries in formal and informal knowledge systems, and funds mobilized to build capacity at grassroots level, while exploring new entrepreneurial opportunities.

The illustrative case studies hint at several potentially useful research and innovation strategies to stimulate cooperation within and among knowledge systems. One such strategy is experimentation and upscaling. Through experiments, actors explore and exploit new opportunities, delving into risky and uncertain markets and technologies, and challenging institutions (Jacobsson and Bergek, 2011). The experiments – and associated policy instruments – would be driven by societal objectives that are ultimately a reflection of the values, preferences and behaviour of individuals and organizations within that society (Rudd, 2004). Experimental projects would be designed to draw upon multiple knowledge bases and thus force multiple actors to collaborate in building cross-disciplinary networks and developing shared expectations and visions. In this way, they may lead to the development of locally relevant solutions to local problems.

A second strategy would involve supporting bottom-up innovation. Technological innovation and community action are important strands of sustainable development that are rarely linked in the policy arena (Seyfang and Smith, 2007). Although some sectoral policies in Kenya acknowledge the role of indigenous knowledge and grassroots initiatives, the strategies systematically neglect bottom-up initiatives as a site of innovation for sustainable development. Yet, when active citizens and strong local democratic institutions 'own' and embody sustainable development, the likelihood for success in shifting the trajectory of development is higher, as locally rooted action generates socially embedded changes in behaviour. Strengthening bottom-up initiatives in Kenya would augur well with the decentralization processes that aim to empower countries.

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KENYA
East Africa

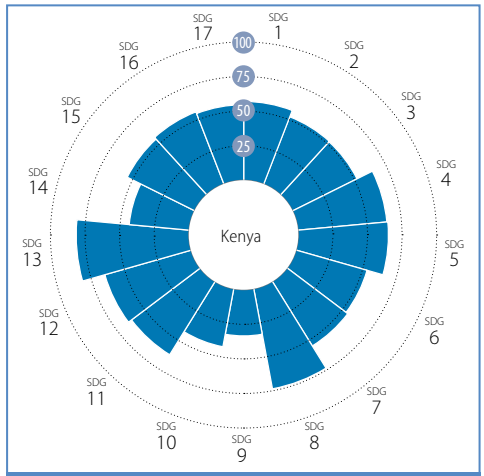
OVERALL PERFORMANCE

Index score

Regional average score

Africa Index Rank

16 (OF 51)



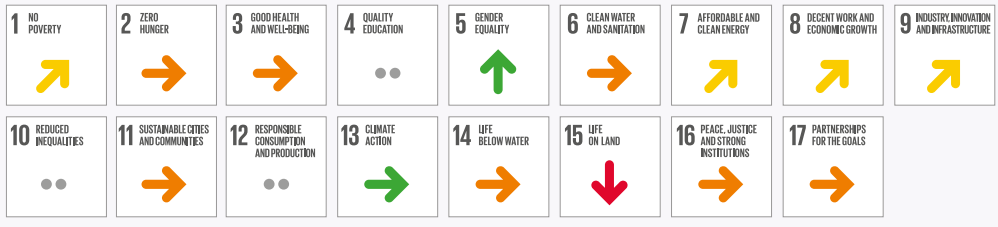
AVERAGE PERFORMANCE BY SDG

COMPARISON WITH OTHER AFRICAN INDICES

	RANK	SCORE
Africa Gender Equality Index (2015)	14 (of 52)	63.3 / 100
Africa Infrastructure Development Index (2016)	18 (of 54)	25.6 / 100
Africa Regional Integration Index (2016)	1 (of 52)	0.76 / 1
Ibrahim Index on African Governance (2017)	13 (of 54)	59.3 / 100

CURRENT ASSESSMENT – SDG DASHBOARD

SDG TRENDS



Notes: The full title of Goal 2 "Zero Hunger" is "End hunger, achieve food security and improved nutrition and promote sustainable agriculture".
The full title of each SDG is available here: https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals

Figure 4.7. Kenya Country Profile 2018.
The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

KENYA
Performance by Indicator

SDG1 – End Poverty	Value	Rating	Trend
Poverty headcount ratio at $1.90/day (% population)	29.0		
Projected poverty headcount ratio at $1.90/day in 2030 (% population)	13.6		
Proportion of population living below the national poverty line	45.9		
Population covered by Social Protection (%)	34.7		
SDG2 – Zero Hunger			
Prevalence of undernourishment (% population)	19.1		
Prevalence of stunting (low height-for-age) in children under 5 years of age (%)	26.0		
Prevalence of wasting in children under 5 years of age (%)	4.0		
Prevalence of obesity, BMI ≥ 30 (% adult population)	7.1		
Cereal yield (t/ha)	1.4		
Fertilizer consumption (kg per hectare of arable land)	28.6		
SDG3 – Good Health and Well-Being			
Maternal mortality rate (per 100,000 live births)	510.0		
Births attended by skilled health personnel (%)	61.8		
Neonatal mortality rate (per 1,000 live births)	22.6		
Mortality rate, under-5 (per 1,000 live births)	49.2		
HIV prevalence (per 1,000)	2.1		
People living with HIV receiving antiretroviral therapy (%)	64.0		
Incidence of tuberculosis (per 100,000 people)	348.0		
Proportion of children under 5 with fever who are treated with appropriate anti-malarial drugs (%)	27.0		
Malaria mortality rate	22.2		
Coverage of Preventive Chemotherapy for Neglected Tropical Diseases (%)	58.7		
Age-standardised death rate due to cardiovascular disease, cancer, diabetes, and chronic respiratory disease in populations age 30–70 years (per 100,000 population)	17.8		
Traffic deaths rate (per 100,000 people)	30.5		
Adolescent fertility rate (births per 1,000 women ages 15-19)	81.8		
Universal Health Coverage Tracer Index (0-100)	55.5		
Age-standardised death rate attributable to household air pollution and ambient air pollution (per 100,000 population)	99.8		
Percentage of surviving infants who received 2 WHO-recommended vaccines (%)	75.0		
Healthy Life Expectancy at birth (years)	63.4		
Subjective Wellbeing (average ladder score, 0-10)	4.5		
SDG4 – Quality Education			
Net primary enrolment rate (%)	81.8		
Mean years of schooling (years)	6.3		
Literacy rate of 15-24 year olds, both sexes (%)	86.5		
SDG5 – Gender Equality			
Proportion of women aged 20-24 years who were married or in a union before age 18	22.9		
Proportion of girls and women aged 15-49 years who have undergone female genital mutilation/cutting, by age	21.0		
Seats held by women in national parliaments (%)	21.8		
Women in ministerial positions (%)	22.7		
Estimated demand for contraception that is unmet (% women married or in union, ages 15-49)	18.9		
Ratio of female to male mean years of schooling of population age 25 and above (%)	81.4		
Ratio of female to male labour force participation rate	91.2		
SDG6 – Clean Water and Sanitation			
Population using at least basic drinking water services (%)	58.5		
Population using at least basic sanitation services (%)	29.8		
Freshwater withdrawal as % total renewable water resources	14.3		
Imported groundwater depletion (m^3/year/capita)	13.7		
SDG7 – Affordable and Clean Energy			
Access to electricity (% population)	36.0		
Access to clean fuels & technology for cooking (% population)	6.2		
Renewable energy share in the total final energy consumption	75.5		
Consumer affordability of electricity	100.0		

SDG8 – Decent Work and Economic Growth	Value	Rating	Trend
5-year average GDP growth per capita (%)	2.7		
Employment-to-population ratio	59.7		
Slavery score (0-100)	80.0		
Adults (15 years and older) with an account at a bank or other financial institution or with a mobile-money-service provider (%)	81.6		
Starting a Business score	83.2		
SDG9 – Industry, Innovation and Infrastructure			
Infrastructure score (0-100)	52.4		
Logistics performance index: Quality of trade and transport-related infrastructure (1=low to 5=high)	3.2		
Research and development expenditure (% GDP)	0.8		
Number of scientific and technical journal articles (per 1,000)	0.0		
Mobile broadband subscriptions (per 100 inhabitants)	25.9		
Proportion of the population using the internet (%)	26.0		
SDG10 – Reduced Inequalities			
Gini Coefficient adjusted for top income (1-100)	50.1		
SDG11 – Sustainable Cities and Communities			
Proportion of urban population living in slums	56.0		
Improved water source, piped (% urban population with access)	61.4		
Satisfaction with public transport (%)	58.0		
Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5) in urban areas (µg/m^3)	16.3		
SDG12 – Responsible Consumption and Production			
Municipal Solid Waste (kg/year/capita)	0.3		
E-waste generated (kg/capita)	1.0		
Natural Resource Value Realization Score	NA		
Production-based SO_2 emissions (kg/capita)	1.3		
Anthropogenic wastewater that receives treatment (%)	0.5		
Net imported SO_2 emissions (kg/capita)	0.6		
SDG13 – Climate Action			
Climate Change Vulnerability Monitor (best 0-1 worst)	0.3		
Energy-related CO_2 emissions per capita (tCO_2/capita)	0.3		
Imported CO_2 emissions, technology-adjusted (tCO_2/capita)	0.3		
CO_2 emissions embodied in fossil fuel exports (kg/capita)	0.0		
SDG14 – Life Below Water			
Percentage of inadequately managed plastic waste	82.7		
Ocean Health Index Goal - Clean Waters (0-100)	49.7		
Ocean Health Index Goal - Biodiversity (0-100)	87.0		
Ocean Health Index Goal - Fisheries (0-100)	40.3		
Mean area that is protected in marine sites important to biodiversity (%)	40.3		
Percentage of Fish Stocks overexploited or collapsed by EEZ (%)	32.4		
Fish caught by trawling (%)	8.0		
SDG15 – Life on Land			
Mean area that is protected in terrestrial sites important to biodiversity (%)	37.5		
Percentage change in forest area (2010-2015)	0.4		
Red List Index of species survival (0-1)	0.8		
Imported biodiversity threats (threats/capita)	0.8		
SDG16 – Peace, Justice and Strong Institutions			
Homicides (per 100,000 people)	5.8		
Conflict-related deaths per 100,000	0.1		
Proportion of the population who feel safe walking alone at night in the city or area where they live (%)	59.0		
Children 5–14 years old involved in child labour (%)	25.9		
Property Rights (0-100)	57.4		
Access to justice (0-100)	34.9		
Corruption Perception Index (0-100)	28		
Public Sector Accountability & Transparency (0-100)	39.3		
Birth registrations with civil authority, children under 5 years of age (%)	66.9		
SDG17 – Partnerships for the Goals			
Tax revenue (% GDP)	19.2		
Government Health and Education spending (% GDP)	11.0		
Level of customs duties on imports	33.8		
Visa Requirement score	48.0		
Governmental Statistical Capacity	57.8		

Figure 4.8. Kenya performance by indicator.

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

References

African Union Commission. 2015. *AU Agenda 2063: The Africa We Want*. African Union Commission.

Akech, M. 2011. Abuse of power and corruption in Kenya: Will the new constitution enhance government accountability? *Indiana Journal of Global Legal Studies*, Vol. 18, pp. 341–94.

Akong'a, J. J. and Kareithi, M. J. N. 1998. Traditional management of drought and famine in Kenya. H. J. Bruins and H. Lithwick (eds), *The Arid Frontier, Interactive Management of Environment and Development*. Springer Netherlands, pp. 165–84.

Bolo, M., Odongo, D. and Awino, V. 2015. *In Pursuit of the Third Mission: Universities and Public Research Institutes as Progenitors of Technology and Innovation in Kenya*. The Scinnovent Centre Discussion Paper 03, Nairobi, The Scinnovent Centre. http://www.innogen.ac.uk/working-papers/1027

Bousquet, A. 2008. *Urban Development in Kenya: Towards Inclusive Cities*. HAL www.archives-ouvertes.fr

Briggs, J. 2005. The use of indigenous knowledge in development: Problems and challenges. *Progress in Development Studies*, Vol. 5, pp. 99–114.

Dei, G. J. S. 2002. African development: The relevance and implications of 'indigenousness'. B. L. Hall, G. J. S. Dei and D. G. Rosenberg (eds.), *Indigenous Knowledges in Global Contexts: Multiple Readings of Our World*. Toronto, University of Toronto Press.

Eshiwani, G. S. 1999. Higher education in Africa: Challenges and strategies for the 21st century. P. G. Altbach and P. McGill Peterson (eds.), *Higher Education in the 21st Century: Global Challenge and National Response*. New York, IEE, pp. 31–38.

Ethics and Anti-Corruption Commission. 2015. *An Evaluation of Corruption in Public Procurement: A Kenyan Experience.* Retrieved from http://www.eacc.go.ke/docs/Evaluation of corruption in the public procurement.pdf

Evans, H. E. 1989. National development and rural-urban policy: Past experience and new directions in Kenya. *Saga Journals: Urban Studies*, Vol. 26, No. 2, pp. 253–66.

GoK. 2008. *Vision 2030*. Nairobi, Ministry of State for Planning.

GoK. 2014*a*. *R&D Survey 2013 – 2014*. Nairobi, Ministry of Higher Education, Science and Technology.

GoK. 2014*b*. Science Technology and Innovation (ST&I) Act of 2013. (The ST&I Act No. 28, Section 32, of 2013 led to the establishment of a National Research Fund (NRF). Legal Notice No. 129 in the Special Issue of *Kenya Gazette Supplement* No. 144 dated 19th November 2014 announcing the commencement of the establishment of NRF as provided in the ST&I Act of 2013.)

Guimón, J. 2013. *Promoting University-Industry Collaboration in Developing Countries* (Policy Brief). Innovation Policy Platform, OECD and World Bank.

Gupta, A. K. 2006. From sink to source: The honey bee network documents indigenous knowledge and innovations in India. *Innovations: Technology, Governance, Globalization*, Vol. 1, pp. 49–66.

Hanlin, R. 2017. *Political Economy of the Kenyan Science Granting Council.* National case study report for the research project 'Case studies of the political economy of science granting councils'. Retrieved from http://hdl.handle.net/10625/56812

Human Development Report. 2016. *Human Development Report for Everyone*. Briefing note for countries on the Human Development Report. Kenya, New York, UNDP.

Jacobsson, S. and Bergek, A. 2011. Innovation system analyses and sustainability transitions: Contributions and suggestions for research. *Environmental Innovation and Societal Transitions*, Vol. 1, pp. 41–57.

Kabita, D. N. and Ji, L. 2017. *The Why, What and How of Competency-Based Curriculum Reforms: The Kenyan Experience.* In-Progress Reflection No. 11 on Current and Critical Issues in Curriculum, Learning and Assessment. Geneva, IBE-UNESCO.

Kenya Forestry Research Institute. 2013. *Strategic Plan 2013 – 2018*. Nairobi, KEFRI.

Kenya National Bureau of Statistics. 2017*a*. Spatial dimensions of well-being in Kenya: Where are the poor? *The Standard*, 27 June.

Kenya National Bureau of Statistics. 2017*b*. *Statistical Abstract 2017.* Retrieved from https://www.knbs.or.ke/download/statistical-abstract-2017/

Klopp, J., Chanin, J., Ngau, P. and Sclar, E. 2014. Globalisation and the urban studio: Evaluating an inter-university studio collaboration in Nairobi. *International Development Planning Review*, Vol. 36, pp. 205–26.

KNBS and SID. 2013. *Exploring Kenya's Inequality - Pulling Apart or Pooling Together?* Nairobi, KNBS.

Kwanya, T. and Kiplang'at, J. 2016. Indigenous knowledge research in Kenya: A bibliometric analysis. *Proceedings of the 11th International Knowledge Management in Organizations Conference on The Changing Face of Knowledge Management Impacting Society*, Article 48, pp. 1–7. New York, ACM.

Lundvall, B.-Å. 2007. National innovation systems – Analytical concept and development tool. *Industry and Innovation*, Vol. 14, pp. 95–119.

MoHEST. 2010. *Mapping and Documenting Indigenous Knowledge in Science, Technology and Innovation in Kenya*. Concept Note. MoHEST.

Moraa, H., Murage, K. and Omenya, R. 2012. *Intellectual Property in Technological Innovations: Perceptions from Tech Startups in Kenyan ICT Hubs*. iHub Research.

Muriithi, P., Horner, D., Pemberton, L. and Wao, H. 2018. Factors influencing research collaborations in Kenyan universities. *Research Policy*, Vol. 47, pp. 88–97.

Mutisya, E. 2014. *Access to Microfinance and Financial Training for Innovative Urban Sustainability: Collective Investment at the Bottom of the Pyramid Segment in Urban Kenya*. Bamends, Cameroon, Langaa Research & Publishing.

Mutisya, E. and Yarime, M. 2011. Understanding the grassroots dynamics of slums in Nairobi: The dilemma of Kibera informal settlements. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*, Vol. 2, pp. 197–213.

Mutisya, E. and Yarime, M. 2014. Moving towards urban sustainability in Kenya: A framework for integration of environmental, economic, social and governance dimensions. *Sustainability Science*, Vol. 9, pp. 205–15.

Mwenda, N. 2003. The challenges of education and development in post-colonial Kenya. *Africa Development*, Vol. 28, pp. 3–4.

Nagao, M. and Mutisya, E. 2015. *Challenges and Opportunities for International Higher Education Collaboration for Africa's Sustainable Development*. Retrieved from http://ir-library.ku.ac.ke/handle/123456789/12749

Ndemo, B. 2015. Effective innovation policies for development: The case of Kenya. S. Dutta, B. Lanvin and S. Wunsch-Vincent (eds), *The Global Innovation Index 2015: Effective Innovation Policies for Development*. Geneva, WIPO.

New World Wealth. 2014. *Wealth in Kenya: The Future of Kenyan HNWIs*. Johannesburg, New World Wealth.

Ngetich, K. A., Freyer, B. and Bingen, J. 2010. Transdisciplinary research in sub-Saharan Africa: Experiences and challenges in Kenya. *Building Sustainable Rural Futures: The Added Value of Systems Approaches in Times of Change and Uncertainty,* 9th European IFSA Symposium, Vienna, 4–7 July, BOKU-University of Natural Resources and Applied Life Sciences, pp. 517–26.

Njoroge, G. N. 2017. Relevance of traditional knowledge in the growth of natural products industry and sustainable environmental management. *JAGST*, Vol. 12, No. 2.

Oba, G. 2001. Indigenous ecological knowledge of landscape change in East Africa. *International Association for Landscape Ecology*, Vol. 19, pp. 1–3.

Ocholla, D. 2007. Marginalized knowledge: An agenda for indigenous knowledge development and integration with other forms of knowledge. *International Review of Information Ethics*, Vol. 7, pp. 1–10.

Okaka, W. T., Migunga, G., Ngaira, J. and Mbego, J. 2016. The prospects of inter-university collaboration for research commercialization and efficient funding of higher education institutions (HEIs) in Africa. Presented at the 6th African Regional Conference of Vice Chancellors and Deans of Science Engineering and Technology COVIDSET 2015. Enugu, Nigeria.

Owuor, J. 2008. Integrating African indigenous knowledge in Kenya's formal education system: The potential for sustainable development. *Journal of Contemporary Issues in Education*, Vol. 2, No. 2, pp. 21–37.

RoK. 2008. *National Development Plan 2002 – 2008: Effective Management for Sustainable Development Growth and Poverty Reduction*. Republic of Kenya.

Rudd, M. A. 2004. An institutional framework for designing and monitoring ecosystem-based fisheries management policy experiments. *Ecological Economics*, Vol. 48, pp. 109–24.

Semali, L. 1999. Community as classroom: Dilemmas of valuing African indigenous literacy in education. *International Review of Education*, Vol. 45, pp. 305–19.

Seyfang, G. and Smith, A. 2007. Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics*, Vol. 16, pp. 584–603.

Shifa, M. and Leibbrandt, M. 2017. Urban poverty and inequality in Kenya. *Urban Forum*, Vol. 28, pp. 363–85.

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network. Available at http://africasdgindex.org

Tobi, H. and Kampen, J. K. 2017. Research design: The methodology for interdisciplinary research framework. *Quality & Quantity: International Journal of Methodology*, Vol. 52, No. 4, 1209–45.

UNDP. 2013. *Kenya's Youth Employment Challenge*. Discussion Paper. New York, UNDP.

UNEP. 2016. *Actions on Air Quality. Policies & Programmes for Improving Air Quality Around the World*. Nairobi, UN Environmental Programme.

UNESCO. 2015. *Mapping Research and Innovation in the Republic of Rwanda*. GO→SPIN Country Profiles in Science, Technology and Innovation Policy, Vol. 4. Paris, UNESCO.

UNESCO. 2016. *UNESCO Science Report: Towards 2030*. 2nd revised edition, Paris, UNESCO. Retrieved from https://en.unesco.org/unesco_science_report

WHO. 2008. *Report on the Review of Primary Health Care in the African Region*. Brazzaville, WHO regional office for Africa.

WHO. 2011*a*. *The Abuja Declaration: Ten Years On*. WHO.

WHO. 2011*b*. *Noncommunicable Diseases Country Profiles 2011*. WHO.

WHO. 2014. *Noncommunicable Diseases Country Profiles 2014*. WHO.

World Bank. 2014. *Decision Time: Spend More or Spend Smart? Kenya Public Expenditure Review.* Nairobi, World Bank Group.

World Bank. 2016. *Poverty and Shared Prosperity 2016: Taking on Inequality,* Washington, DC, International Bank for Reconstruction and Development/World Bank Group.

World Bank. 2017. *Kenya Economic Update: Poised to Bounce Back? Reviving Private Sector Credit Growth and Boosting Revenue Mobilization to Support Fiscal Consolidation*. Washington, DC, World Bank Group.

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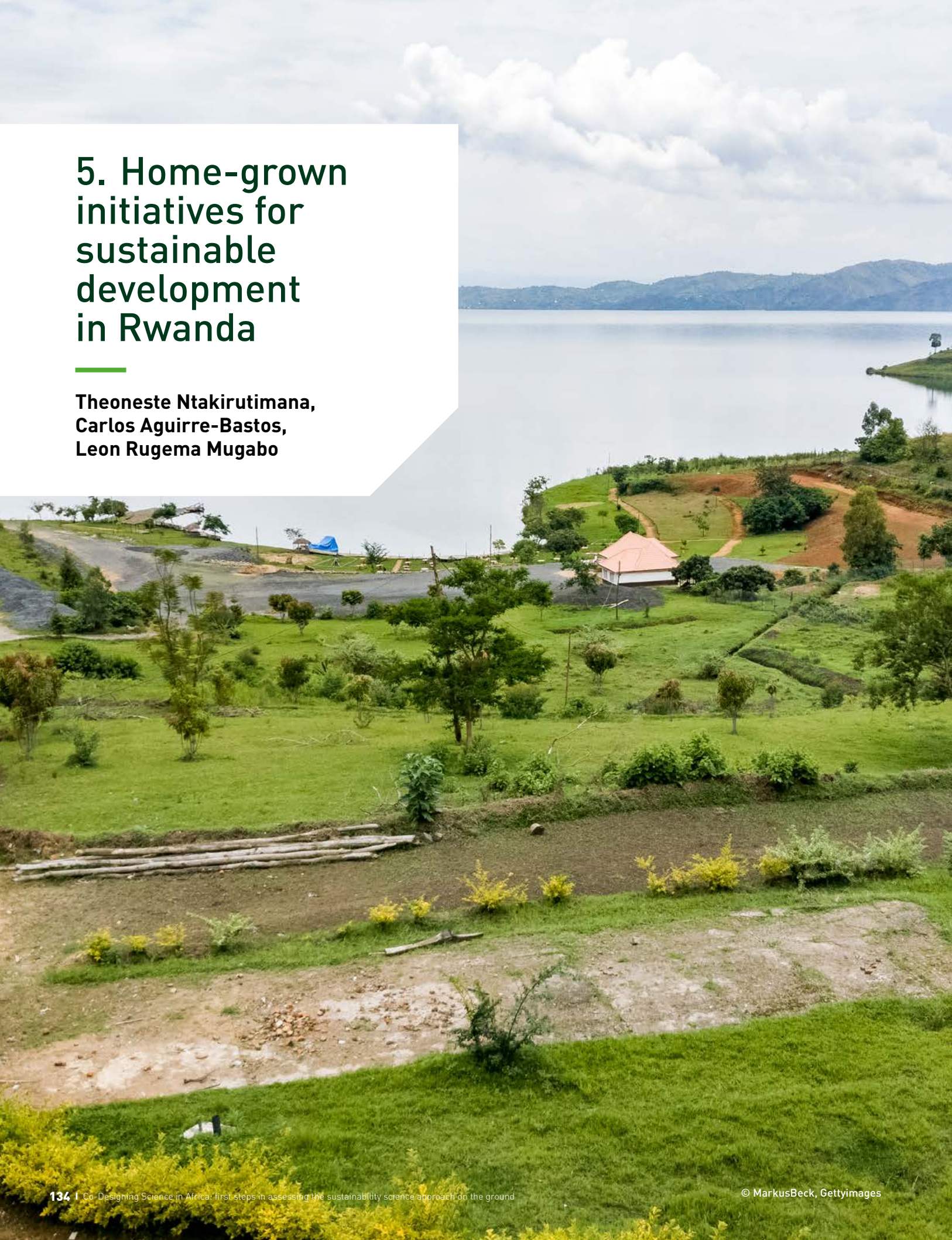
5

Home-grown initiatives for sustainable development in Rwanda

5. Home-grown initiatives for sustainable development in Rwanda

Theoneste Ntakirutimana, Carlos Aguirre-Bastos, Leon Rugema Mugabo



5.1. Introduction

Rwanda is a country that has come a long way after the internal strife of the early 90s. As signalled by Tony Blair in 2014,[1] today the country is a beacon of hope and progress has been extraordinary 'as Rwandans themselves have shaped the policy to heal the nation'. In fact, Rwanda's development since the genocide in 1994 is a unique story of social and economic progress based on the country's core values of self-sufficiency (*kwigira*) and dignity (*agaciro*), resilience, determination and hard work. These values have been the basis on which home-grown solutions have been built, and which also show that non-STEM (science, technology, engineering and mathematics) disciplines can be rallied to drive economic transformation.

During the genocide, one million people perished and three million were internally or externally displaced. The economy shrank by half down to the second lowest per capita income in the world, four-fifths of the population lived below the poverty line and life expectancy fell to below 30 years. This situation reversed radically after the conflict, thanks to prudent micro- and macroeconomic policies, strategies, laws, regulations and institutional restructuring, which – coupled with a favourable international context and the contribution of better-managed foreign aid – have created a conducive environment for the acceleration of the Rwandan economy. Simultaneously, social advances took place, with important improvements in health and education systems, all of which had a direct positive impact on communities' livelihoods.

Despite these developments, there still remain challenges to be faced in the short, middle and long terms in order to achieve a middle-income status by 2020, and to transform into an active knowledge-based economy as proposed in Vision 2020 and the UN Sustainable Development Goals 2030 (SDGs). The national objectives for 2020 set in 2000 include increasing per capita income to US$900 from US$220 in 2000; reducing the poverty rate to 30% from 60.4%; and increasing the average life expectancy to 64 years from 49 years.

At the same time, plans for the longer-term future of the country are set out in its Vision 2050,[2] which aspires to take Rwanda to upper middle-income status by 2035 and high-income status in 2050, thereby providing its people with a high standard of living.

One key challenge facing Rwanda in its quest to become a sustainable knowledge-based economy is the need to develop capacities in science, technology and innovation (STI), particularly given the rapid advances taking place worldwide. Facing such a challenge will inevitably require an appropriate research and innovation system.[3]

Another key challenge is related to environmental sustainability. Rwanda is highly dependent on natural resources and agriculture is the main economic activity. Small land holdings and insufficient investment in soil and water conservation to cope with Rwanda's topography are pressing environmental problems. Climate change is likely to add to existing pressures, including soil erosion through more intense rains. Furthermore, demographic growth is also pressing on the environment, especially considering the high rate of urban growth. Today, Rwanda is the most densely populated country in Africa with 507 inhabitants per km^2 for a total population of 12.5 million people.

This chapter discusses recent developments and issues relating to efforts made by the country towards sustainability. Section 5.2 presents a brief political, social and economic background, with a short discussion on Vision 2020 and Vision 2050 – both guiding the country's development paradigm. Section 5.3 gives an overview of the main environmental problems facing Rwanda and section 5.4 discusses some key policies and strategies adopted to face such challenges, including associated mitigation strategies.

Section 5.5 discusses and summarizes the main findings of several in-depth evaluations made over the past five years on the research and innovation system which, as previously mentioned, is key to meeting sustainability goals in Rwanda.

Section 5.6 gives an overview of home-grown initiatives that the Government of Rwanda (GoR) has promoted or embarked on to create a conducive environment for sustainability and describes three of them in detail as selected case studies.

5.2. The socio-economic situation

Since the mid-90s, the Rwandan economy has experienced strong economic growth averaging 8% per annum during the period 2001–2015 and exceeding global and regional growth rates during the period 2010–2017 (World Bank, 2017). To make economic growth more sustainable and responsive to

1 www.theguardian.com/commentisfree/2014/apr/06/rwanda-genocide-beacon-hope-healing-nation

2 The draft Vision 2050 is being drawn up, and stakeholders from the public and private sectors, SCOs, NGOs, academic, communities and development partners are being engaged to finalize the blueprint.

3 The term 'research and innovation system' encompasses 'the science, technology and innovation system', 'the science, research, technology and innovation system' and 'the national innovation system'.

social demands, in 2000 the Government prepared a long-term development strategy entitled Vision 2020 (GoR, 2000) and adopted several implementation policies, plans and strategies. Vision 2020 represents an ambitious plan to raise the people of Rwanda out of poverty and transform the country from a low-income agriculture-based economy to an active knowledge-based and service-oriented economy with middle-income country status by 2020.

Vision 2020 sets out six broad objectives:

a) **Good governance and a capable government:** Understood as accountability, transparency and efficiency in deploying scarce resources, and also meaning a State respectful of democratic structures and processes and committed to the rule of law and the protection of human rights in particular.

b) **Human resource development and a knowledge-based economy:** Raising the general welfare of the population, and improvements in education and health services that can be used to build a productive and efficient workforce.

c) **Private sector-led development:** Supporting the establishment of a viable private sector that can become the main growth engine of the economy, not only conducive to economic growth, but also to ensure a vibrant middle class of entrepreneurs, who will help develop and embed the principles of democracy. Vision 2020 also claims that, although foreign direct investment should be encouraged, a locally-based business class remains a crucial component of development.

d) **Infrastructure development:** The rehabilitation and development of infrastructure is a crucial aspect in lowering the costs of doing business in Rwanda, which will attract domestic and foreign investment. This includes: efforts in land use management; urban development; transport; information and communication technologies (ICTs); energy; water; and waste management.

e) **Productive high-value and market-oriented agriculture:** Agricultural policy orientation needs to be overhauled; promoting intensification should be rewarded to increase productivity and achieve growth rates of 4.5 to 5% per year. This will occur if the production of high-value crops and modern livestock management are in place. The goal should replace subsistence farming by a fully cash-crop agricultural sector.

f) **Regional and international integration**: It is crucial to pursue an open and liberal trade regime to minimize trade barriers and implement policies that encourage direct foreign investment. Thus, accessing larger regional markets will benefit the investment programme, such as infrastructure to promote Rwanda as a communication and telecommunication hub. Furthermore, Rwanda's comparative strategic position can be converted into an operation trade point.

In addition, Vision 2020 stresses several key cross-cutting issues: gender equality, natural resources and environmental sustainability, and science, technology and ICT access.

The adoption of the Second Economic Development and Poverty Reduction Strategy (EDPRS 2) (GoR, 2013), underpinned by Vision 2020, is closely associated with sustainability challenges. EDPRS outlines the goal for growth acceleration and poverty reduction through four thematic areas: a) economic transformation; b) rural development; c) productivity; and d) youth employment and accountable governance. The objectives that EDPRS 2 sets to be achieved by 2020 are given in **Table 5.1** below. Some of these objectives will be difficult to reach, as, for example, growth will be well under the 11.5% target, and extreme poverty will still persist in some parts of the country.

Table 5.1. EDPRS 2 objectives and their corresponding Vision 2020 targets

Objectives	Vision 2020 targets
Rapid economic growth to middle-income status	• GDP per capita of $1,240 • Average GDG growth of 11.5%
Increased poverty reduction	• Poverty reduced to 20% • Extreme poverty eliminated
More off-farm jobs, more urbanization	• 3.2 million off-farm jobs • 35% of population urban
Reduced external dependency	• Exports growth of 28% p.a.
Private sector as engine of growth	• Private sector takes dominant share of investment

Source: GoR, 2013

As noted above, the implementation of previous measures and those derived from Vision 2020 has ensured Rwanda's successful economic growth. A recent report (IMF, 2018) indicates that growth in 2017 is expected to reach 5.2%, well above growth averages for sub-Saharan Africa, and will accelerate in the medium term, leading to average growth above 7% over the next three years. In 2016, Rwanda was considered the most efficient government in Africa (WEF, 2016).

The main drivers of the economy in 2016 have been services (50.3%); agriculture (34.6%); and industry (15.1%) (CIA, 2017). The inflow of donors' financial assistance triggered a higher contribution from the service sector. These are mainly benchmarked by investment in basic infrastructure, such as telecommunications, finance, tourism and productivity in agriculture; the industry sector is still in need of growth.

The above developments respond to firm government policies, greater exchange rate flexibility, public spending restraint and prudent monetary policy. In addition, the government has implemented a 'Made in Rwanda' policy to encourage domestic production of goods such as cement and rice. These efforts led to an accumulation of foreign exchange reserves by the end of 2017.

The performance of Vision 2020 on social indicators has shown substantial progress; Rwanda is now close to or exceeding the average for lower middle-income (LMIC) countries and well ahead of its low-income (LIC) peers, as shown in **Table 5.2**.

Table 5.2. Progress on social indicators

Indicators	Initial condition (1994, unless specified)	Latest (2015, unless specified)	Low-income countries average (2015, unless specified)	Lower middle income countries average (2015, unless specified)
% of population below national poverty line	80	39 (2014)	..	31
Immunization, measles (% of children aged 12-23 months)	76 (1996)	97	78	80
Improved sanitation facilities (% of population with access)	39	83	28	52
Improved water source (% of population with access)	62	85	66	90
Births attended by skilled health staff (% of total)	27 (2000)	91	49 (2012)	59 (2012)
Maternal mortality ratio (modelled estimate, per 100,000 live births)	1 270	210	496	251
Mortality rate, under-5 (per 1,000 live births)	300	50	76	53
Life expectancy at birth, total (years)	29	66.6 (2017)	61 (2014)	67 (2014)

Sources: World Development Indicators and National Institute of Statistics of Rwanda (see also World Bank, 2017)

Other social indicators show that inequality, as measured by the GINI coefficient, has reduced from 46.6 in 2011 to 44.7 in 2014 (NISR, 2016*a*). The country has also levelled gender inequality. As shown in **Table 5.3**, for example, it has been ranked first in parliamentary representation at the world level (IPU, 2017). This progress in gender has enabled women to advance economically and review the legal framework, i.e. today, women can own land and girls can inherit from their parents.

Vision 2020 ends in 2020 and other strategies such as EDPRS 2 and its respective Sector Strategic Plans (SSPs) and District Development Strategies (DDSs) ended in June 2018. Furthermore, a new seven-year government plan was required for the mandate of the newly elected government to cover the period from 2017 to 2024. Upon considering these deadlines, the 13th National Dialogue (*Umushyikirano*) in 2015 requested the development of a new 30-year vision, Vision 2050, which is today under discussion among national stakeholders.[4]

Table 5.3. Women in parliament (top six countries)

World rank	Country	Number of seats in lower or single house	Number of women	Percentage
1	Rwanda	80	49	61.3
2	Bolivia	130	69	53.1
3	Cuba	612	299	48.9
4	Iceland	63	30	47.6
5	Nicaragua	92	42	45.7
6	Sweden	349	152	43.6

Source: IPU, 2017

Vision 2050 focuses on five priorities, which underpin the design, policies and initiatives of the National Strategy for Transformation (NST-1):

a) **High quality and standards of life**: Moving beyond meeting basic needs to ensure a high standard of living to transform the lives of households and individuals. The focus is on sustained food security, universal access to water, sanitation,

energy, education and healthcare, housing, financial services, social protection, and environmentally friendly surroundings and national security.

b) **Developing modern infrastructure and livelihoods**: Modernization towards SMART green cities, towns and rural settlements includes well-designed transport facilities and services, and efficient public and private services.

c) **Transformation for prosperity**: Developing high-value and competitive jobs and sectors through improved productivity and competitiveness through diversified tourism, business and financial services, IT and technology, logistics and aviation, agro-processing, science and technology innovation, construction and extractive industries.

d) **Values**: The values underpinning economic and social progress are self-reliance and self-determination, dignity, unity and Rwandan identity, integrity, equity (including gender), transparency and openness, participation in the global community, good governance and accountability, community participation, local innovation and national stability.

e) **International cooperation and positioning**: Rwanda will forge its own place in the world in the context of regional integration, multi- and bilateral cooperation aiming at freedom from aid dependency and increased pan-African and South-South cooperation.

The development planning framework for Vision 2050 and NST-1 includes *inter alia* a set of sectoral challenges related to Future Earth's Knowledge Action Networks (KAN).[5] The study of these challenges can provide a preliminary view on the opportunities in Rwanda for research activities contributing to national and global transformation towards sustainability.

The implementation instrument for the remainder of Vision 2020 and for the first four years of Vision 2050 will be NST-1, from 1 July 2018 until 30 June 2024. NST-1 will integrate far-sighted, long-range global and regional commitments by embracing:

a) The Sustainable Development Goals (SDGs), consisting of 17 Goals with 169 targets, across a range of economic, social and environmental issues.

b) The Africa Union Agenda 2063 and its First 10-Year Implementation Plan 2014–2023, which is dedicated to the building of an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena. The Agenda has eight plans spanning social and economic development, integration, democratic governance, and peace and security.

c) The East African Community (EAC) Vision 2050, which focuses on initiatives for job creation and employment. The Vision identifies development enablers that will create jobs which are integral to long-term transformation, value addition and acceleration of sustained growth. These enablers include infrastructure, transport networks, energy and information technology, and industrialization.

NST-1 mainstreams these and other obligations, including the COP 21 Paris Agreement on Climate Change,[6] but its prime influence is to fulfil the aspirations of Vision 2050. Further, NST-1 constitutes the Government Programme for 2017–2024 and combines the previous standalone 7YGP and the EDPRS into one single plan.

Sector strategic plans (SSPs) and district development strategies (DDSs) are being elaborated in the above context. Running in alignment and in parallel with NST-1, they cover a six-year period starting July 2018. Vision 2020 catch-up plans will also be integrated under NST-1. Both Vision 2050 and NST-1 planning and execution continues to use the existing tried-and-tested development planning and implementation frameworks.

The new strategy identifies seven priority sectors: 1) agriculture, 2) manufacturing, 3) energy, 4) mining, 5) urbanization, 6) meetings, incentives, conventions and exhibitions, and 7) transport and logistics. It considers that there exist a set of factors that favour strong growth and structural transformation of the Rwandan economy, including a visionary and committed leadership upholding high ethical standards, fostering innovation and providing security and stability. Positive factors also include a low starting income, indicating great potential for rapid convergence with more prosperous economies, a favourable demography and the potential for strong agriculture and livestock productivity. Finally, membership of the EAC and other regional blocks will allow stronger trade channels to support this transformation.

5.3. Main sustainability challenges

Rwanda faces a number of sustainability challenges. The country's growth has been overly dependent upon exploitation of natural resources, thus increasing their depletion. Biodiversity loss is related to the disappearance, conversion, fragmentation, pollution or degradation of its natural flora, fauna, and land and water resources. The main pressures on natural resources are

5 Future Earth (n.d.).

6 The Intended Nationally Determined Contribution for the Republic of Rwanda was presented on 06/10/2016.

extracting activities such as mining, poaching, poisoning and illegal wildlife hunting, or encroachment on protected areas. The introduction of alien and invasive species, damming, water extraction, wetland draining and commercial fishing, among others, have also been detrimental to the environment (see, for example, REMA, 2015*a*).

The environmental profile prepared by the European Commission (EC, 2006) identified the following key problems:

a) Degradation of soil due to loss of vegetation cover, overexploitation and inappropriate agricultural systems, and lack of anti-erosive measures.

b) Loss of biodiversity due to deforestation and wetland mismanagement.

c) Deforestation due to demographic pressure, uncontrolled production of domestic energy (charcoal and firewood), migration and resettlement of the population.

d) Pressure on wetlands (clearing of natural marshes, hydro-agriculture development which is not associated with protection of catchments basins), resulting in a reduced capacity of flood accumulation (risk of flooding and lake sedimentation).

e) Multiplication of aquatic weeds along the Akagera and Nyabarongo rivers.

A significant portion of land in Rwanda is dedicated to agriculture, with natural forest cover relegated to four isolated national parks facing significant pressures from their surrounding populations. Although the country has achieved significant improvements in crop yields in the past years, climate change increases crop diseases, destroying agriculture systems and increasing food insecurity. Climate change affects rainfall patterns, disease outbreaks, temperature regimes that result in flooding, erosion, droughts, food insecurity and loss of wildlife. Understanding and predicting these changes is crucial to ensure that socio-economic transformation goals are met.

In agriculture, among other ecosystem services, irrigation, chemical fertilizer and pesticide applications are pitfalls that impact on soil and water quality, and thus human health. Moreover, unsustainable land-use practices related to agriculture affecting land preservation include deforestation, the loss of fragile ecosystems, overcultivation and overgrazing.

The major drivers of deforestation in Rwanda are high population densities, land fragmentation, a lack of jobs in non-agricultural sectors and high poverty levels. The collection of firewood and other forest products, illegal logging, charcoal production, bush fires, mining and invasive liana are also drivers for deforestation. However, improvements in total forest area from 18% in 2014 to 19.5% in 2015 (World Bank, 2017) should be recognized.

Although the Rwandan urbanization rate is the world's lowest, the urban population's annual growth rate of 4.5% exceeds by far the world average of 1.8%. Almost half of urban dwellers are concentrated in Kigali City. Urbanization challenges of small and densely populated areas exert pressure on water, environment, sewage and public health services, disproportionally affecting poor urban communities. These challenges require appropriate planning to avoid sprawl and marginalization, which create social division and increase energy demand, carbon emissions and ecosystem degradation.

Sustainability challenges require appropriate skills to support the transformation from a traditional agricultural to an active knowledge-based society. In agriculture, a large proportion of farmers still employ unsustainable agricultural practices due to low technology provision and capacity-building programmes.

Gender inequity is also a sustainability issue. Women dominate informal street vending activities and are exposed to sexual and gender-based violence and harassment in public spaces. Women equally dominate water collection where water is rare, increasing exposure to violence.

The United Nations Women's agency in Rwanda (UN Women, 2016) and Kigali City municipality have identified and implemented priority physical improvements in 14 minimarkets. This activity allowed access for women hawkers to look for more productive markets, and the construction of a minimarket for Kigali City hawkers. Kigali City's approach in constructing safe minimarkets for women and girls has helped to solve the problem of informal street hawking and has contributed to the achievement of SDG 11 by serving the city's hygienic and environmental needs.

Rwanda is highly vulnerable to climate change. Since 1970, it has experienced a temperature increase of 1.4 °C higher than the global average, and current projections for East Africa show an increasing trend in rainfall intensity in both rainy seasons, which is likely to increase floods and storms, landslides and crop losses. Temperature rises may increase the spread of vector-borne diseases, impacting animal and human health, and negatively affecting crop yields, impacting food security and export earnings of tea and coffee (Hughes and Gasore, 2014). The cost of climate change has been estimated to be about 1% of GDP (Drakenbergand Cesar, 2013). Under these conditions, Rwanda depends heavily on the success of global mitigation and the country's adaptive capacity.

Photo 5.1. Women are the basis of food production in the continent, especially in Rwanda, as the genocide had a bigger impact on men. © CIAT, Neil Palmer, Flickr, CC BY-NC-SA 2.0

Another sustainability challenge is the health status of Rwandans, which remains poor. Mental health problems, due largely to the horrors of the genocide and its aftermath, are prevalent in a society that is not equipped to deal with these problems. Preventable diseases like HIV/AIDS and malaria remain a burden on the Rwandan economy, in terms of direct costs to poor and vulnerable households (UNDP, 2008). On the other hand, fertility is high – in Rwanda, on average, a woman has six children, with the resulting rapid population growth creating a major public health and development issue.

Another social challenge is related to the level of education, which in Rwanda, remains low, despite the implementation of policies such as mandatory education for primary school (6 years) and lower secondary schooling (3 years). The present average is still 3.3 years lower than that expected. There are also recognized insufficiencies in quality, such as in the recruitment of teachers which, combined with the increase in enrolment, results in a slightly worsening qualified teacher-to-pupil ratio of 68:1 (Fortune of Africa, 2017).

5.4. National policies addressing environmental problems

5.4.1. Governance

Rwanda has implemented a large number of sustainability-related policies and regulations in recent years, mainly following the adoption of the Rwanda Environmental Policy in 2003 (GoR, 2003). This policy defines the governance mechanisms for managing environmental issues; it established the Rwanda Environment Management Authority (REMA) and set up committees for environmental protection at decentralized levels–province, district and town. Furthermore, the policy previews the enactment of a legal framework for improved environmental management and principles for citizens' participation in environmental protection.

5.4.2. National Green Growth and Climate Change Resilience Strategy for climate change and low carbon development

Rwanda has defined the promotion of a green economy as a key foundation to its sustainable development. This is enshrined in the National Green Growth and Climate Change Resilience Strategy (GGCR) (GoR, 2011), and is also part of the Poverty Reduction Strategy Phase 2 (GoR, 2013), which encourages green economic opportunities to reduce economic costs, create jobs and make a positive environmental impact. The adoption of these strategies has given the country a competitive edge for low carbon economic development opportunities.

The strategy defines a general Vision for 2050, foreseeing Rwanda as a climate-resilient, low-carbon economy, with a strong services sector, low unemployment and low levels of poverty. Its guiding principles include:

a) Economic growth and poverty reduction;

b) Good regional and global citizenship;

c) Sustainability of environmental and natural resources;

d) Gender equality and equity; and

e) Welfare and wellness of all citizens in a growing population.

The GGCR's strategic objectives are:

i) To achieve energy security and a low-carbon energy supply that supports the development of green industry and services;

ii) To achieve sustainable land use and water resource management that results in food security, appropriate urban development and preservation of biodiversity and ecosystem services; and

iii) To achieve social protection, improved health and disaster risk reduction that reduces vulnerability to climate change.

The strategy calls for the execution of 14 'Programmes of Action', covering many different problems areas, as shown in **Figure 5.1**.

The special fund for environment and climate change, FONERWA, supports the GGCR strategy. It provides technical and financial support to the best public and private projects that align with Rwanda's commitment for a green economy. The FONERWA model has proven catalytic in directly facilitating resource mobilizations into the fund (US$50 million, according to the April 2016 review) (CIDT, 2016).

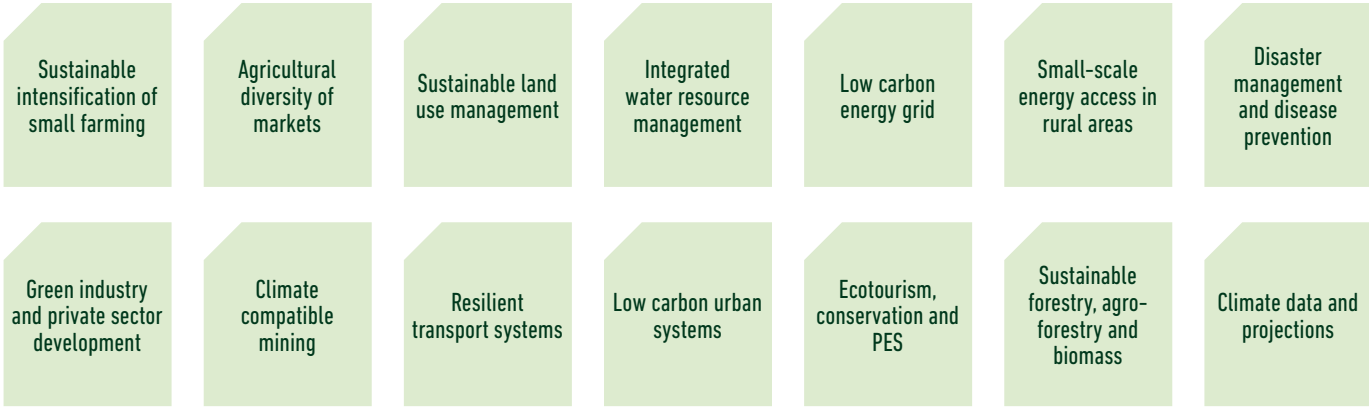


Figure 5.1. GGCR 14 Programmes of Action.
Source: GoR, 2011.

Included in the strategy are policy statements and options with regard to population and land-use management, management and utilization of natural resources, and management of other socio-economic matters, as well as the necessary arrangements for the implementation of the policy itself. While ensuring the quality of life and environment, the strategy aligns with poverty reduction policies providing a framework for reconciling environmental, social and economic issues. The strategy is being supported in part by the United Nations Environment Programme (UNEP) and the German International Development Agency project 'Operationalizing Green Economy Transition in Africa' (Rwanda, Mozambique, Kenya, Ethiopia and Ghana).

The project developed a 'toolkit' (REMA, 2015*b*) that highlights key assessment methods, and a practical step-by-step guide to plan and implement a green economy at subnational level. The toolkit covers ten sectors, including agriculture and food, fisheries, forestry, tourism, energy, water, transport, waste, industry and environment.

5.4.3. Sustainable development goals in Rwanda

Rwanda has taken a leading role in the Great Lakes region of Central Africa in facing the challenges posed by the SDGs. The country was selected to pilot SDGs on governance and rule of law in recognition of its experience in measuring these developmental variables by using the Rwanda Governance Scorecards. Further, the country is home to the Africa Sustainable Development Goals Centre, expected to promote research and innovation to achieve African development goals and, through the University of Rwanda, hosts the Regional Sustainable Development Solutions Network (UN SDSN) for the Great Lakes, including members from Burundi, the Democratic Republic of Congo, the Republic of Congo and Rwanda.

At the national level, several steps have already been taken to proceed to 'SDG Domestication' (GoR, 2016*a*):

i) The MDG progress report and SDG road map have been submitted to the government cabinet for discussion.

ii) A preliminary assessment of SDG indicators was carried out at the National Statistics Institute.

iii) The Ministry of Finance and Economic Planning (MINECOFIN) has translated the SDGs into Kinyarwanda, one of the four official languages of the country, and distributed them to participants in National Dialogue Council.

iv) A gap analysis has assessed the domestication level of SDGs in the existing national development plans.

In this last analysis, 14 strategic plans were consulted, together with the Poverty Reduction Strategy and Vision 2020. Of the 169 SDG goals, 38 (23%) were found to be fully reflected in the strategic plans, while 51 (30%) were only partially reflected; 51 (30%) were not reflected and 29 (17 %), which are globally monitored, were weakly reflected or not reflected in the national development frameworks. Such an analysis leaves a significant amount of work for planners and, in particular, for the research and innovation system.

5.4.4. Other policies and strategies addressing sustainability problems

The Government of Rwanda adopted several other policy and strategy definitions related to sustainability. Some of the most important are:

Organic Law Determining the Modalities of Protection, Conservation and Promotion of the Environment in Rwanda (2005)[7]

This law determines the modalities of protecting, conserving and promoting the environment with the aim of improving people's livelihoods and habitats. It provides fundamental principles related to the protection of the environment, with the intention of promoting natural resources while discouraging any hazardous and destructive activity that may degrade the environment. In addition, the law provides ways of promoting social welfare by considering the equal distribution of existing wealth; the durability of resources with a special emphasis on equal rights for present and future generations; and a guarantee to all Rwandans of sustainable development that does not harm the environment. Furthermore, the law provides for the setting-up of strategies to protect and reduce negative effects on the environment, and for restoration of the environment where it has been degraded.

Law Determining the Organization, Functioning and Mission of the National Fund for the Environment (FONERWA, 2012)

This law provides for the mobilization and management of (i) resources used in activities aiming to protect environmental and natural resources and (ii) funds to be used in the fight against climate change and its impacts. The law also supports public institutions, associations and individuals in carrying out activities to protect the environment conduct research and manage climate change.

Law on Biodiversity (2013)

This law determines modalities for the management and conservation of biological diversity within Rwanda and stipulates that a competent authority shall conduct research on the protection and conservation of biodiversity and its sustainable use.

A set of other legal norms and regulations have been issued over the last ten years that in one way or another impact on sustainability, *inter alia*:

a) Law establishing the Rwanda Energy, Water and Sanitation Authority (2010).

b) Statute establishing the International Renewable Energy Agency (2011). This statute ratified the convention establishing the International Renewable Energy Agency (IRENA), signed in Bonn on 26 January 2009.

c) Kigali City urban development and policy framework (Kigali City Master Plan) that provides a long-term vision for the city, based on fundamental pillars of sustainable urban development. It provides guidelines, strategies and schematic designs for various urban sectors, including transport and infrastructure (water, sanitation, sewage and power).

d) Policy on Science, Technology and Innovation (2006) that will be detailed in the next section.

e) Intellectual Property Policy (2009), for the development of a special law on traditional knowledge and genetic resources (GoR, 2009*a*).

f) Higher Education Policy (2008).

In Rwanda's pursuit to build a green and climate-resilient nation, several other goals have been achieved. REMA (2017) has identified a set of several key milestones for 2016, including the following:

- In October 2016, Rwanda successfully hosted a ground-breaking international meeting that passed the Kigali Amendment to the Montreal Protocol. The country was instrumental in bringing together 197 countries to adopt what is hailed as the single largest contribution the world has made towards keeping global temperature rises below 2 °C.
- On 3 December 2016, UNEP honoured President Paul Kagame with the 2016 Champion of the Earth award for policy leadership. The prize is the United Nation's highest environmental honour and was given to the president in recognition of Rwanda's outstanding achievements in environmental protection.
- The creation of the Gishwati-Mukura National Park in 2016, now the fourth such protected reserve in Rwanda, aims to conserve the country's ancient rainforests that are home to a wide range of flora and fauna, including primates, chimpanzees and mammals. The new park also boasts 60 species of trees, including indigenous hardwoods and bamboo.

7 https://repositories.lib.utexas.edu/bitstream/handle/2152/4960/4063.pdf?sequence=1

- Rwanda was selected to host the Regional Forest Landscape Restoration Centre of Excellence for Eastern and Southern Africa. The centre is being operated in partnership with the IUCN and was officially inaugurated at a ceremony in Kigali to mark the International Day of Forests on 21 March 2016.
- In October 2016, Rwanda joined more than 80 nations to ratify the Paris Agreement on Climate Change. As already mentioned, the country presented its Intended Nationally Determined Contribution (INDC) on 6 October 2016.
- In November 2016, Rwanda joined the Climate and Clean Air Coalition, an international coalition aimed at reducing emissions of short-lived climate pollutants. Under its voluntarily assumed obligations, the country increased taxes on older vehicles and introduced mandatory emissions testing for all vehicles. It has also encouraged the use of gas to substitute biomass burning. The establishment of the Rwanda Climate Observatory, discussed further in Section 5.6, will provide the data needed to make informed decisions on how to reduce short-lived pollutants.
- The adoption of the law governing the preservation of air quality and prevention of air pollution in Rwanda marked a big step towards preventing air pollution in the country. The law was published in the official gazette in June 2016.
- On 2 September 2016, Rwanda hosted the 12th *Kwita Izina* (gorilla naming ceremony), during which 22 baby gorillas were named. This event was attended by thousands of community members, who have been key to the gorillas' protection, as well as hundreds of leaders from the conservation and tourism industries. A special 'Conversation on Conservation' held during *Kwita Izina* discussed the preservation of wildlife and biodiversity in Rwanda and beyond.

Recently, Rwanda adopted the 'Smart Green Villages' concept with the aim of supporting urbanization practices for integrated food, water and energy self-sufficiency, for the sustainable livelihood of the rural and vulnerable poor (REMA, 2015*b*; see also UNEP, 2011). The country's National Urbanization Policy (2015) explicitly encourages collaboration among public and private institutions, civil society and academia in creating sustainable urban habitats. The implementation of green city plans has generated many critical research questions, in particular how urban planning strategies can reduce a city's vulnerability to climate change.

In addition to these milestones, there were a number of another notable achievements in the recent past, including the 'Most Green Country' award for climate action at the UN Climate Talks in Morocco, the launching of model green villages in Rweru and Gashaki, the launch of the 2016/17 Forest Planting Season that will see 23 million trees planted, and the continued efforts of Rwanda's Green Fund (FONERWA), which to date has created 90,000 green jobs and reforested 21,847 ha of land.

5.5. The National Research and Innovation System

Science and technology, including ICT, is one of three cross-cutting areas of Vision 2020 and in recognition of its importance, the country has made 'significant efforts by putting in place the governance as well as the physical infrastructure as enablers for a sustainable development of the National Science, Technology, Research and Innovation System' (GoR, 2012*a*, p.5).

Several studies and assessments have been conducted to describe and analyse the functioning of the innovation system in Rwanda. In 2013, the Government requested the Global Initiative (Farley et al., 2013), a review of the 2005 National Science and Technology Policy; in 2015, UNESCO carried out an in-depth study of the Rwanda National Research and Innovation System under the GO→SPIN initiative (UNESCO, 2015); and in 2017, UNCTAD conducted a review, as part of its Reviews Programme (UNCTAD, 2017). The main findings of these studies will be discussed later in this section.

In 2005, the cabinet approved a National Science, Technology, Research and Innovation Policy, in line with Vision 2020 (GoR, 2006). The overarching aim of the policy is:

'To integrate Science, Technology, Scientific Research and Innovation in a framework that shall include capability building, technical transfer initiatives, and the promotion of innovation, in the context of the issues facing Rwanda. Science, Technology and Scientific Research shall be the catalyst to underpin all public and private sector activities to enable Rwanda's Vision 2020 to be realized.' (GoR, 2006, p. 6)

Within this aim, the policy's specific objectives are given as:

1. **Knowledge acquisition and deepening**: Promoting science and technology education as an essential strategy to achieve human development objectives.
2. **Knowledge creation**: Reinforcement of research units in higher learning institutions, coupled with investment in training, and development of international partnerships in high quality research to meet the development needs of Rwanda.

3. **Knowledge transfer**: As STI is a cross-cutting issue, reinforcement of STI capacity will help many of the economic and social sectors in Rwanda achieve their objectives.
4. **Innovation**: Needs to be encouraged at all levels to help stimulate economic growth. Special attention is being paid to the available capacity at national level to process scientific and technological innovations or inventions that can lead to the acquisition of intellectual property ownership.

It was expected that policy implementation would strive to achieve a set of general policy outcomes (GoR, 2012*a*):

a) An integrated national research and innovation plan linked to national socio-economic development and competitiveness.

b) Efficient funding and support of research and innovation.

c) Effective national research and innovation governance, programme coordination, monitoring and evaluation.

d) Increased valorization of the impact of research and innovation outputs through efficient knowledge transfer and business networks.

e) Competent and capable human resources through intensive promotion of a strong innovation culture, as well as STEM education and professional training.

In order to achieve the policy objectives, the policy proposes a full set of strategies and frameworks. **Figure 5.2** provides an overview of an integrated framework designed to create linkages between policy, capacity and major country issues, and emphasizes a cluster approach, not only to national policy and projects, but also to external relationships with donor communities and the international community.

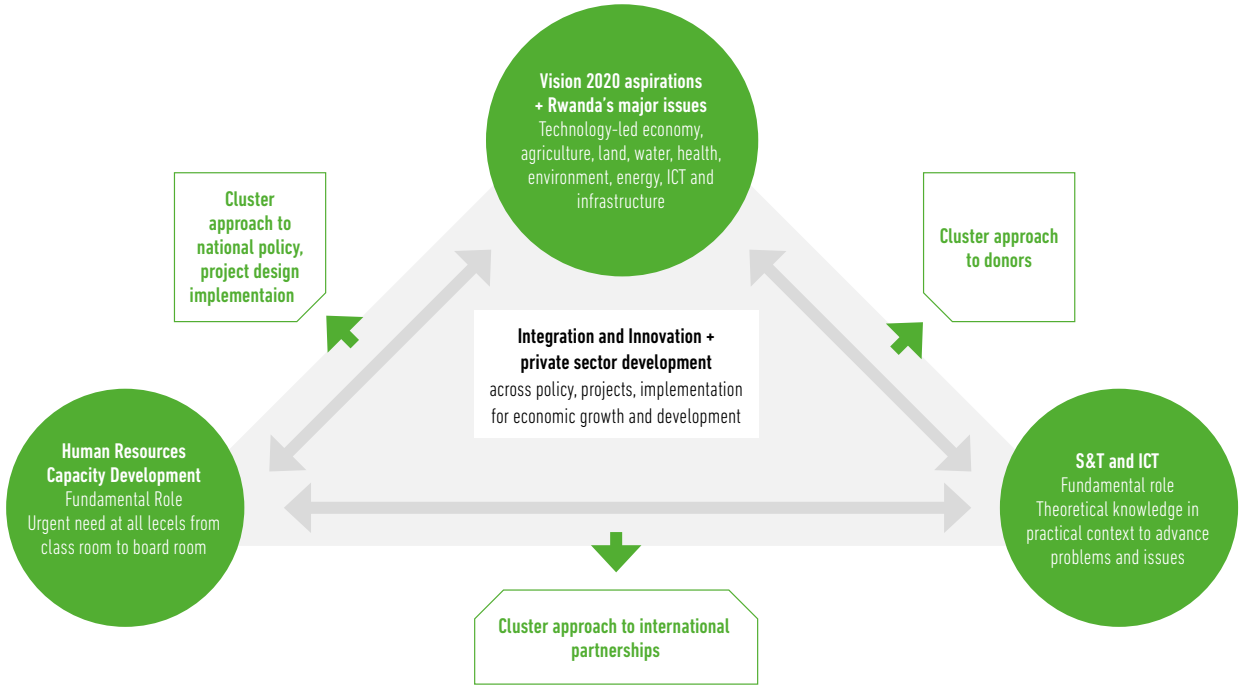


Figure 5.2. Overview of integrated innovation framework linkages.
Source: UNESCO, 2015.

In addition, in order to operationalize the policy objectives, the government is striving to establish centres of excellence in research, with specialized and complementary mandates, which will further serve as regional (East Africa and Africa) research hubs. These include:

a) Centre of Excellence in Biodiversity and Natural Resources Management.

b) Global Climate Observatory, in partnership with MIT and COMESA.

c) Centre of Excellence in ICT, in collaboration with Carnegie Mellon University and the African Development Bank.

d) Centre of Excellence in Biomedical Engineering.

e) Regional Centre of Excellence – Health Supply Chain Management.

f) Partner Institute for the International Centre of Theoretical Physics.

g) African Institute for Mathematical Science.

Within the World Bank strategy of supporting science and technology, and the project Eastern and Southern Africa Higher Education Centres of Excellence II (ACEII), 4 out of the 24 centres of excellence which qualified through the competitive process are already operational in Rwanda: 1) ACE in Internet of Things; 2) ACE for Data Science; 3) ACE in Innovative Teaching and Learning Mathematics and Science; and 4) ACE in Energy for Sustainable Development.

The adopted policy also defines a full set of sectorial STI policies covering 13 areas, of which science and technology policies in agriculture and animal husbandry, environment, energy, education and health, biotechnology, water and sanitation, have a direct bearing on sustainability issues.

The environmental sector policy objective states that 'Scientific techniques shall be applied for the sustainable management of natural resources including biodiversity, water and soil conservation, marshlands improvement and issues related to climate change' (GoR, 2006, p. 13). These objectives should then be reached pursuing a strategy that includes:

1. Public awareness and participation, and education programmes – to address public understanding on the essential linkages between environment and development, thus promoting individual and community participation.
2. Environmental, land use policy and planning – to address the sustainability, security and equitable use of resources, and to prevent degradation of land, water, vegetation, deforestation and air.
3. Technology improvement/alternative energy sources.
4. Reforestation programmes.
5. Capacity-building and human resource development – to develop local capacity in all areas of the environment, such as environmental impact assessment, forestry, etc.
6. Conservation programmes, including biodiversity, ecology, species, habitat and wildlife management – to conserve and enhance biological diversity of the ecosystem.

Figure 5.3 shows the organizational chart of the national innovation system and the distribution of responsibility for implementation of the adopted policy. There are five distinct levels:

a) Policy-planning level (policy design).

b) Promotional level (funding).

c) Performance level (scientific research, technological development and productive innovation).

d) Science and technology services.

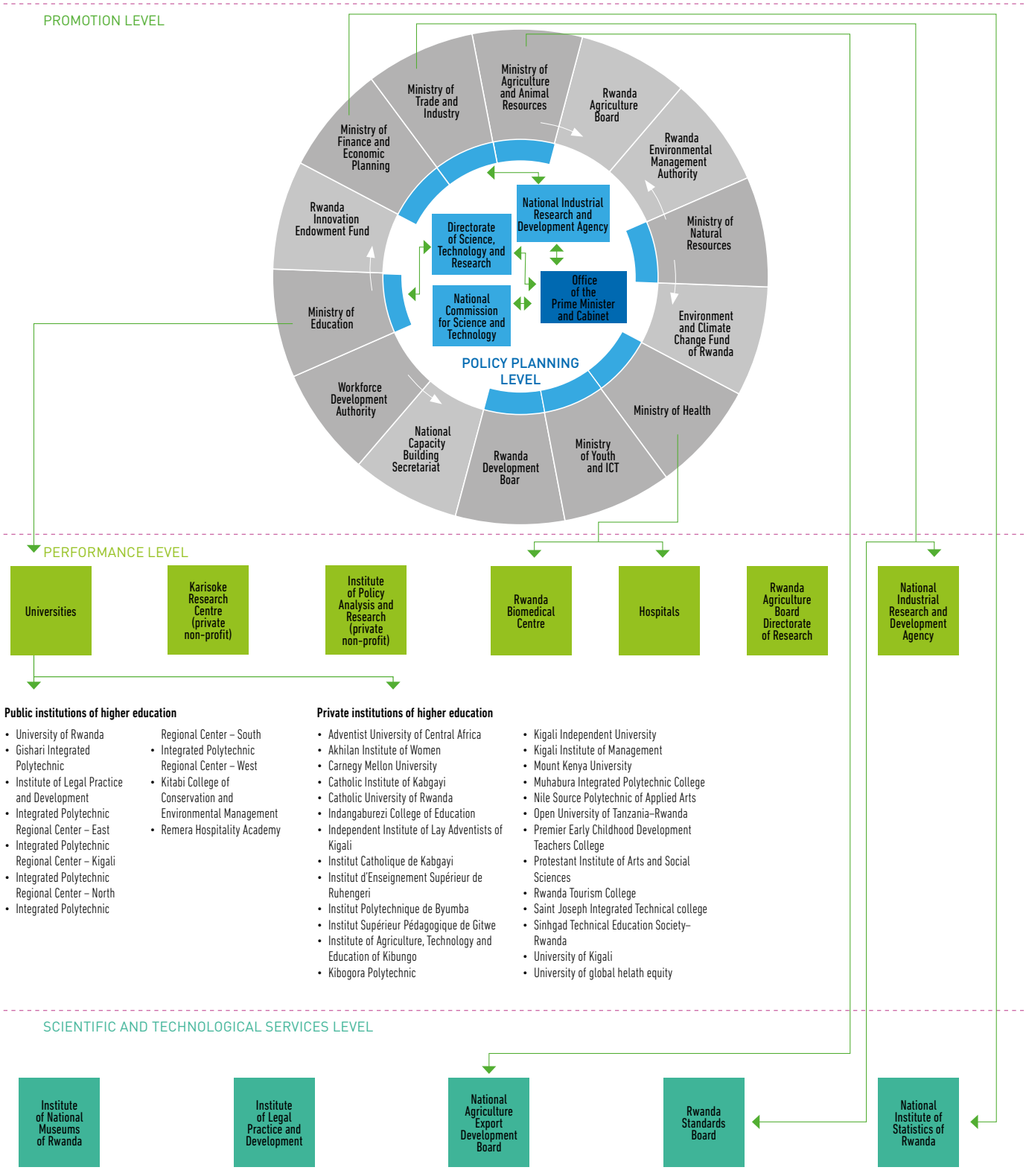
e) Assessment/evaluation level.

The three main implementation units that have been established to oversee the development of science, technology and research in Rwanda are:

1. National Commission for Science and Technology (NCST) established under Law Number 80/2013 of 11 September 2013, whose main functions are to advise the government on policies, legislation and regulation, and monitor policy implementation.
2. Science, Technology, Innovation and Research (STIR) Unit of the Ministry of Education, whose main responsibility is to advise the Minister of Education on policies and strategies for science and technology as they relate to programmes in the education sector.
3. National Industrial Research and Development Agency (NIRDA), established under Law Number 51/2013 of 28 June 2013, whose main functions are to implement national industrial policy, patent inventions and traditional knowledge in relation to industrial development, and promote the trade of research products. In addition, the agency carries out industrial and technology development research, through the establishment of technology incubation centres and pilot plants with rural industrialization.

Photo 5.2. Rice farming in communal village lands is mostly done by women
© UNESCO/J. Chaves-Chaparro

Rwanda national innovation system



Public institutions of higher education

- University of Rwanda
- Gishari Integrated Polytechnic
- Institute of Legal Practice and Development
- Integrated Polytechnic Regional Center – East
- Integrated Polytechnic Regional Center – Kigali
- Integrated Polytechnic Regional Center – North
- Integrated Polytechnic Regional Center – South
- Integrated Polytechnic Regional Center – West
- Kitabi College of Conservation and Environmental Management
- Remera Hospitality Academy

Private institutions of higher education

- Adventist University of Central Africa
- Akhilan Institute of Women
- Carnegy Mellon University
- Catholic Institute of Kabgayi
- Catholic University of Rwanda
- Indangaburezi College of Education
- Independent Institute of Lay Adventists of Kigali
- Institut Catholique de Kabgayi
- Institut d'Enseignement Supérieur de Ruhengeri
- Institut Polytechnique de Byumba
- Institut Supérieur Pédagogique de Gitwe
- Institute of Agriculture, Technology and Education of Kibungo
- Kibogora Polytechnic
- Kigali Independent University
- Kigali Institute of Management
- Mount Kenya University
- Muhabura Integrated Polytechnic College
- Nile Source Polytechnic of Applied Arts
- Open University of Tanzania–Rwanda
- Premier Early Childhood Development Teachers College
- Protestant Institute of Arts and Social Sciences
- Rwanda Tourism College
- Saint Joseph Integrated Technical college
- Sinhgad Technical Education Society–Rwanda
- University of Kigali
- University of global helath equity

Figure 5.3. Organizational chart showing Rwanda's research and innovation system (Circa 2015).
Source: Updated from UNESCO (2015: p. 147).

Some key output indicators show that the system performs well considering its financial difficulties. **Table 5.4** shows indicators for the agricultural sector, which is the only one with updated information. The survey to collect this data was made possible by the African Science and Technology Indicators Network.

Table 5.4. Main agricultural R&D indicators

FTE researchers spending	2005	2006	2007	2008	2009	2010	2011
Total, public (million constant 2005 PPP)	18.6	18.8	18.9	20.2	21.8	23.4	27.2
Total, public (million constant 2005 US$)	6.2	6.3	6.3	6.8	7.3	7.8	9.1
Total public (million constant 2005 LCU)	3 472.1	3 501.9	3 515.9	3 768.0	4 057.9	4 358.5	5 071.5
As share of agriculture GDP (%)	0.6	0.6	0.6	0.6	0.6	0.6	0.7
Salaries (% of total spending)	-	-	-	-	-	44.2	40.2
Operating and programme costs (% of total spending)	-	-	-	-	-	51.1	54.2
Capital investments (% of total spending)	-	-	-	-	-	4.7	5.6
FTE researchers' funding							
Government (% of total funding)	-	-	-	-	-	52.5	55.4
Donors and development banks (% of total funding)	-	-	-	-	-	38.8	39.2
Sales of goods and services (% of total funding)	-	-	-	-	-	8.7	5.4

Sources: UNESCO 2015 (note: financial data excludes the higher education sector); Agriculture Science and Technology Indicators (ASTI) database.

Table 5.5 shows the number of full-time equivalent (FTE) researchers and technicians engaged in R&D activities between 1965 and 2009. Data corresponding to the years between 1965 and 1995 were published in the *UNESCO Statistical Yearbook*. Data corresponding to years 2008 and 2009 were estimated for the study *Mapping Research and Innovation in the Republic of Rwanda* (UNESCO, 2015).

Table 5.5. Main human resources indicators for R&D (FTE personnel)

Year	Total personnel	Researchers	Technicians	Administrative
1965	n/a	18	n/a	n/a
1967	n/a	19	n/a	n/a
1980	n/a	48	n/a	n/a
1981	117	54	36	27
1982	130	62	41	27
1983	149	64	55	30
1984	164	69	60	35
1985	n/a	71	n/a	n/a
1990	n/a	101	n/a	n/a
1995	122	70	16	36
2008*	n/a	263	n/a	n/a
2009*	n/a	306	n/a	n/a

*Note: UNESCO estimate based on surveys of FTE researchers in the higher education sector, and in the government sector within agricultural sciences.
Source: UNESCO Statistical Yearbook 1972, 1982 and 1998.
Source: UNESCO, 2015.

Figure 5.4 shows the top 20 institutions in Rwanda by number of publications registered in the Scopus database from 1995 to 2016. The leading institution by far is the University of Rwanda (670), with almost three times more publications than the Ministry of Health (229).

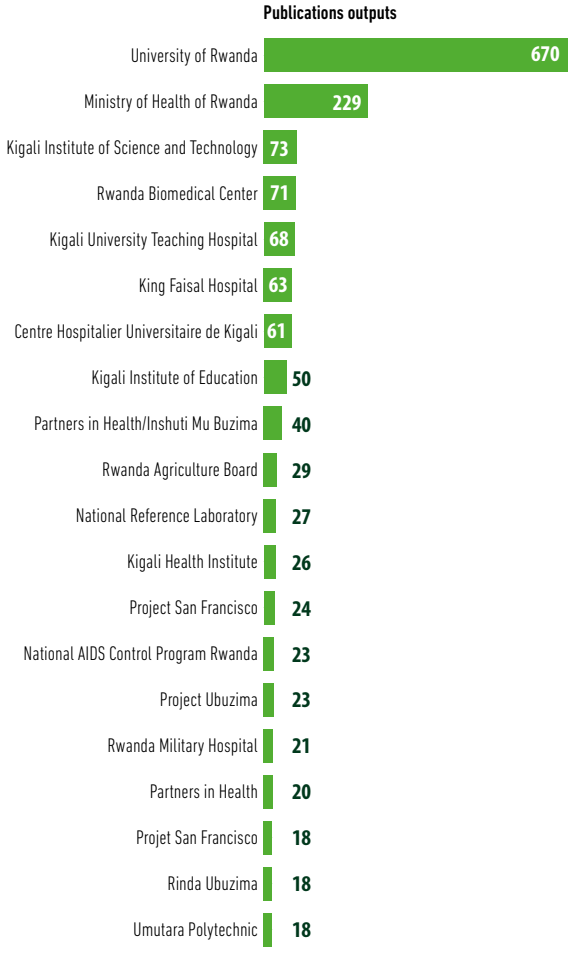


Figure 5.4. Publications outputs from main R&D institutions.
Source: UNESCO, 2015.

Within the research and innovation system, there are several participating institutions with mandates related to the environment and sustainability. Of these, the Rwanda Environment Management Authority (REMA) and Rwanda Agriculture Board (RAB) Directorate of Research are particularly important, due to their role in the general socio-economic context of the country.

Universities are a key element of the national research and innovation system. Several research analyses (HECR, 2016) demonstrate that Rwanda has invested heavily in higher education because of its enormous human resource shortage, exacerbated by decentralization. Investments have been targeted at a number of critical knowledge areas, such as accounting and economics, science and technology, public administration and management, and agriculture with rural development.

An important step in the reform of the higher education system was the merger in 2013 of seven public higher learning institutions to form the current University of Rwanda: 1) the former National University of Rwanda; 2) Kigali Institute of Science and Technology; 3) Kigali Institute of Education; 4) Institute of Agriculture and Animal Husbandry; 5) Kigali Health Institute (KHI); 6) School of Finance and Banking; and 7) Umutara Polytechnic. The intention behind the merger was to establish a world-class university that could actively contribute to the global knowledge economy.

The returns on this investment in human capital have been substantial: a huge number of Rwandan graduates have excelled in the higher education sector worldwide. However, quality in higher education is still a significant challenge. The education sector needs to adapt its curricula to the local context, such that graduates can systematically exploit their knowledge to competently serve rural areas.

The evaluation by Farley et al. of Rwanda's national STI policy (2013) recognizes the existing high level of commitment to STI-based education, including increased access for women and girls. However, it also points out that the lack of practical exposure hinders the relevance and employability of graduates. The evaluation signals that suboptimal incentives and metrics for research impede research productivity, and that there is a mismatch between research output and market needs that hinders potential impact. In addition, it acknowledges that there is an inadequate commercialization and communication of research results, and that the appropriate transfer of knowledge interactions with global networks needs to be strengthened, including a greater focus on enabling knowledge transfer functions.

Farley et al. draw attention to the fact that growing numbers of innovation and entrepreneurship programmes mean thinly spread resources and duplication of efforts. The reduced impact of resource-limited projects within a vast number of 'national priorities' is generally reflected in the policies of many other developing countries. Another important observation in the evaluation is that national policy fails to include the essential element of innovation culture.

UNESCO's in-depth study (2015) provides a detailed discussion of the strengths, weaknesses, opportunities and threats of the system, which is summarized in **Table 5.6** in a SWOT matrix.

The UNCTAD (2017) review on Rwanda had three fundamental goals: 1) to offer the country an assessment of the framework conditions and interactions required for a functional national research and innovation system; 2) to draw attention to the main policy challenges in strengthening the national research and innovation system, based on a review of four sectors: energy, ICTs, agriculture and industry; and 3) to provide recommendations for strengthening policies and propose measures that may improve national technological capacities and encourage innovation.

Based on extensive field work, the review recognized that Rwanda has made remarkable social and economic progress in the last twenty years, and to become a knowledge-based economy, it is recognized that technology development (and in particular ICTs) is central to the strategy. Also, it is recognized that innovation is taking place and that policy-makers are keenly aware of innovation as an enabler of economic growth.

ICTs play a major role in transforming the economy and are integral to achieving Rwanda's Vision 2020 and 2050 goals. ICTs are transformational, offering opportunities to close technological gaps through rapid technology uptake in all sectors, and underpinning the social and economic development of the country. Rwanda envisions ICTs as a driver of the country's transformation (GoR, 2014*a*).

The challenges facing Rwanda's quest for an ICT-enabled transformation for socio-economic development are enormous, ranging from research and innovation to the need for sufficient numbers of highly-skilled personnel in the ICT sector (GoR, 2016*b*). The National Council for Science and Technology has identified software engineering, cyber security, mobile application development, smart city and sustainable urban development, e-commerce and e-banking, e-health and telemedicine as priority areas.

Table 5.6. SWOT analysis of Rwanda Research and Innovation System.

Strengths	Weaknesses
• Strong improvements of governance indicators • Positive long-term trends in human development indicators since 1994 • Good environment for doing business • SETI as a cross-cutting pillar for sustainable development • Motivation for research and innovation • Expansion of tertiary education • Expansion of ICT infrastructure	• Small economy and inequality • SETI policy coordination and implementation • Small pool of researchers • Absence of a SETI gender policy • Absence of any explicit human resources policy for science and engineering • Low research and innovation productivity • Limited demand for SETI • Low participation of business/enterprise sector in R&D • Inadequate set of SETI operational policy instruments and funding mechanisms • Indigenous knowledge remains largely disregarded • Erratic energy supply derailing progress in SETI
Opportunities	**Threats**
• Improve synergism and policy coherence through new institutional framework • Human capital development in STEM • Improve gender equality in STEM • National Research Fund • Availability of special external funding mechanisms for environmental R&D • Networking at national, regional and international levels • Interconnectivity initiatives for educational institutions • R&D and value-addition • Legal protection of indigenous knowledge	• Limited human capacity • Adverse effects of climate change • Overdependence on foreign consultants to design domestic SETI policies • Plethora of SETI strategic priorities dilutes policy effectiveness

Source: UNESCO, 2015.

Despite the advances, the review identifies a set of factors that will affect Rwanda's ability to take advantage of STI and that require the close attention of policy-makers:

a) The development of policy and actions supporting the strengthening of a Rwandan national system of research and innovation. These should be established at the highest level of leadership and their institution should result in decision-making rather than the providing of guidance.

b) Investment in human capacity development relevant to the knowledge economy. This necessitates strong links between education and training institutions, and proposed or functional centres of excellence with support and funding from NCST and NRIF.

c) Aligning the skill demands of industry with the output of schools, universities and vocational training institutions, and revisiting the enrolment intake for degrees and qualifications that have poor employment results.

d) The development of absorptive capacities in mainstream services, sectors and industries, and the use of high-tech innovation loci, such as the ICT industry, innovation hubs and centres of excellence, to leverage the development of technological receptiveness throughout the entire economy – this requires energizing the business community. Outside ICTs, the business culture is conservative and concedes that incentives for investment, let alone technological upgrading, are insufficient.

e) Consolidation of the innovation funding and financing ecosystem. There are several funding agencies, all with slightly different funding capacities, and looking for different deals in overlapping areas. Improved clarity on funding opportunities for the innovation end of the STI spectrum, including commercialization and scaling up, is needed. The establishment of the NRIF may contribute to resolving this important issue.

f) Achieving a critical mass of R&D programmes and projects that will tip Rwanda's development into a knowledge economy trajectory. R&D must aim to contribute directly to solving the problems and challenges in production, in the real economy. Rwanda's continued progress and participation in regional integration and EAC processes will stimulate its industries and sectors to increase their innovation performance as its firms and entrepreneurs are challenged by larger and more competitive markets.

5.6. Research and innovation for sustainable development

5.6.1. Research and innovation for sustainability

Efforts to connect capacity-building in STI with sustainable development are still in their early stages, but important steps are being taken in that direction. In 2011, the Government of Rwanda began working with MIT and COMESA to develop a world-class climate research programme in the country – **The Global Climate Observatory**. The observatory would measure climate change and atmospheric agents, develop climate education in schools and universities, and capacity-building in climate, air pollution and meteorology.

The proposed observatory should be built at Mount Karasimbi at 4,507 m, and feasibility studies have been under way for some time. At present, an interim observatory has already been established on the summit of neighbouring Mount Mugogo (2,590 m), where several instruments have been deployed. This observatory is the latest addition to a global network of observatories, known as the Advanced Global Atmospheric Gases Experiment (AGAGE), and the first such observatory in Africa. It is collecting atmospheric data around the clock on meteorology, climate, and approximately 50 greenhouse gases. It will significantly improve the understanding of regional emissions of greenhouse gases, especially those coming from agricultural activities, wildfires, large urban areas and deforestation.

A key element in the joint programme is the new University of Rwanda master's degree in Atmospheric and Climate Science, developed in collaboration with MIT. The high frequency measurements generated from the climate observatory, along with Rwandan meteorological, agricultural, air pollution and other data, will support master's thesis projects.

5.6.2. Home-grown initiatives for sustainable development

A large number of initiatives have been launched by Rwanda to implement SDGs based on traditional values and practices. Rwanda is a good example of the African region's potential, and of the global need to mobilize all kinds of knowledge systems and stakeholders in the co-designing of science in order to achieve national development goals and, more broadly, SDGs.

The Rwanda Governance Board (RGB) is the country's centre of excellence for governance policy and research, the application of innovations and top-level service provision geared towards fostering accountability in governance, democracy and decentralization for sustainable development. RGB promotes the principles of good governance and decentralization, conducts research and policy analysis related to governance, monitors the practices of good governance, coordinates and supports media sector development, registers political organizations, provides policy advocacy to government, and enhances citizen participation in the implementation of various governance initiatives.

One of the key missions of RGB is to document and assess home-grown initiatives. Below is a table of the main home-grown initiatives that have contributed to Rwanda's transformation journey during the last decade. **Table 5.7** shows the most important of these, and some are discussed further below.

Table 5.7. Examples of home-grown initiatives addressing socio-economic problems

Governance	Social	Economic	Political
• Governance Month for accountability and/or transparency • *Abunzi* (mediation committees) • Access to Justice Bureaus (MAJ)	• *Girinka* ('One cow per poor family') • *Ubudehe* (Participatory socio-economic development mechanism)	• *Umuganda* (Community work) • *Imihigo* (Performance contracts) • *Agaciro* Development Fund • Land use consolidation • Crop intensification programme	• *Umushyikirano* (National dialogue) • *Umwiherero* (National leadership retreat) • Governance Month • *Itorero / Ingando* (National Academy of Civic Education) • Army Week

Source: GoR, 2014.

Abunzi (community mediators)

Traditionally, the term *abunzi* meant 'those who reconcile' or those 'who bring together', which comes from the verb *kunga* (= to reconcile) in Kinyarwanda. According to Rwandan tradition, *abunzi* were men known in their communities for personal integrity and honesty, who were often asked to facilitate reconciliation in cases of conflict. The opposing parties would bring these community mediators to help settle disputes without alienating the other party, and they were considered as problem-solvers. Not only were they required to settle the disputes, but they were also asked to restore harmony within the affected community.

Nowadays, *abunzi* is considered as a hybrid combination of tradition with modern methods of justice and conflict resolution. It was reintroduced in 2004, in the hope of reducing caseloads for the courts and decentralizing the legal process, thereby offering the population a simple and cost-effective way to access the justice system. The system has gained more recognition due to its successful methods of conflict resolution. By 2012, more than 30,768 *abunzi* were operating throughout Rwanda.

Because of a*bunzi*, the time spent in courts to settle cases has gradually reduced by 86.7%. Moreover, the economic cost has reduced by 84.2% and the ability to mitigate conflicts between litigants has risen by 80.1%. Other advantages include community participation in the mediation process, whereby 67.3% of the population has been involved, and the freedom to choose a judge by the plaintiff and defendant, which has increased by 56.7%.

People participating in *abunzi* were said to be honourable and unable to take bribes. RGB reports state that *abunzi* are 'people with integrity, respectful of all parties and capable of remaining impartial during hearings' (RGB, 2014).

Imihigo (performance contract)

The term itself is the plural of *umuhigo* (= to vow to deliver a service), which translates as 'performance contract'. The system was introduced in 2006 and includes the concept of *guhiganwa*, which expresses the idea of competing among parties. This dates back to pre-colonial practices, whereby an individual sets goals to be achieved within a specific period. The person setting the goals must complete them within the guiding principles and be determined to overcome any possible challenges that arise.

Since the introduction of *imihigo*, there have been many successes. It has increased accountability and increased the efficiency of citizen-centred development activities and programmes. The practice has even extended to other areas, such as ministries, embassies and public service staff, and has evolved into a tool for planning, implementation, performance evaluation and accountability for all public institutions.

Ubudehe (social categorization for collective action and mutual action)

Ubudehe refers to the long-standing tradition of Rwandan practices and its culture of collective action and mutual support to solve problems within a community (Shah, 2011). It is not known exactly when *ubudehe* was first practised, but it is thought to date back more than a century. The focus of traditional *ubudehe* was mostly on cultivation. Since 2008, it has gained international recognition as a highly successful development programme, especially after the UN Public Service Award to Rwanda for 'Better management: Better public service'.

Because of *ubudehe*, local communities can be involved in creating their own social maps, visual representations and collection of data measuring local poverty. As part of the programme, each community is provided with a bank account, with which they buy their own livestock, build clean water sanitation, classrooms, terraces and health centres. In 2006–2007, 9,000 communities undertook projects through *ubudehe* and in 2007–2008 that number gradually increased to 15,000. By 2012, around 55,000 collective actions were being led by communities themselves with assistance from 30,000 *ubudehe* facilitators (RGB, 2014).

Girinka ('One cow per poor family' programme)

The word itself translates as 'May you have a cow', and is usually used for 'One cow per family', a very old Rwandan culture that has existed for centuries. This is mainly because, according to Rwandan tradition, giving a cow to a neighbour meant sealing a bond of friendship, a culture that is profoundly respected by Rwandans. The act of giving symbolizes unity and social cohesion; it was either a sign of gratitude or given as a gift during marriage ceremonies. In the hope of reviving Rwandan culture, the practice of giving cows as a symbol was re-introduced to restore national unity. The traditional practice was thus embedded in development programmes as a home-grown solution.

The programme 'One cow per poor family' was introduced as a response to alarmingly high rates of malnutrition among children under 5 years old. Its main purpose was to deliver cow milk to those children from poor households to help them have a more nutritious and balanced diet. Providing a cow to households also gave additional value, in that it enabled them to grow their agricultural products through improved soil fertility and increase their family income by selling dairy products.

The increased number of cows among beneficiaries leads to an increase in manure. As a result, agricultural productivity increased. So far, since the start of *girinka* in 2006, more than 198,000 families have received cows. Due to the high milk production throughout the country, the 'One cup of milk per child' programme in schools was established. Between 2009 and 2011, milk production increased by 11.3%, rising from 334.7 million l to 372.6 million l, and meat production increased by 9.9% over the same period. Additionally, increased crop production leads to better food security.

A comprehensive third Food Security and Vulnerable Analysis and Nutrition Survey (CFSVA), conducted in March/April 2012, revealed that almost four-fifths (79%) of households had an acceptable food consumption and could be considered 'food secure' (NISR, 2012). It was reported that in comparison with 2005–2006, a higher proportion of people (47%) were able to afford cattle nationally. This was because 4% of rural households received a cow under the 'One cow per family' programme.

While *girinka* cannot take full credit for improving health in Rwanda, it has nonetheless played a significant role. It has contributed to reducing malnutrition across the country, especially among children below the age of five. As reported by the Demographic Health Survey in 2010, children whose growth was restricted fell to 44% in 2010 from 51% in 2005. The percentage of emaciated children fell to 3% from 5% and that of underweight children fell to 11% from 18% in the same period.

Traditional medicine

A medical system is normally called 'traditional' when it is practised within the country from where it originated (WHO, 2001). It includes a diversity of health practices, approaches, knowledge and beliefs incorporating plant, animal, and/or mineral-based medicines; spiritual therapies; manual techniques and exercises applied singly or in combination to maintain well-being, and to treat, diagnose, or prevent illness.

In Rwanda, treatment using traditional herbs is common. The knowledge is passed on in families from generation to generation creating a group of well-respected healers, even though they do not have any formal education. Traditional medicine in Rwanda is practised by recognized and registered traditional healers who have been accredited by the community where they work.

Itorero (civic education)

Itorero refers to a cultural school where Rwandans would study the foundations of the nation, such as patriotism, language, social relations, team sports, dancing, songs and defence. This system targets youth to encourage them to understand their culture. *Itorero* increases their awareness of cultural values and prepares them for leadership.

Itorero was readopted in 2009 by the government of Rwanda to bolster the nation's social fabric and to ignite Rwandan cultural values (GoR, 2012*b*). This followed an assessment of cultural practices and development programmes, where the country's leaders realized that some behaviour was hindering the achievements of certain programmes due to a lack of Rwandan values. Graduates from the school are called *intore* and their comportment is greatly appreciated by Rwandan society. *Itorero* created an opportunity for participants to develop a sense of responsibility and a problem-solving approach, through a combination of patriotism and professional knowledge.

A special organization, the National Itorero Commission, was created specifically for this activity. There are many graduates each year: Between 2007–2012, 284,207 *intore* made up of teachers, local leaders, executive secretaries, farmers, community policing committees and diaspora were trained. In 2016, 2,500 trainees were brought together for training on Rwandan values and taboos. The aim was to enhance the leadership culture and foster a sense of responsibility and patriotism.

Umushyikirano (National dialogue council)

Translated, *umushyikirano* means 'a place to meet, share knowledge and question each other'. This is governed by the Rwandan constitution 2003, Article 140, where the forum is designated to debate on the country's issues, national unity and local government. This annual meeting began on 28 June 2008 and is coordinated by the office of the prime minister. It is chaired by the president of the country and gives Rwandans the chance to ask questions directly to their leaders in different departments. The president invites people from overseas to the forum, such as members of the diplomatic community, the media, local government, representatives of the Rwandan community abroad, cabinet and parliament. Non-participants can also contribute to discussions through social media such as Twitter, SMS and Facebook, and can follow live on radio and TV (RGB, 2014).

Umwiherero (National leadership retreat)

The term *umwiherero* means 'retreat' in Rwandan culture. It consists of a gathering of leaders in a specific place to discuss issues relating to their communities and aims to bring about resolutions to those issues. It can also refer to 'moving to a quiet place to discuss issues with a small group of people'. The government of Rwanda, through the office of the president of Rwanda, and in collaboration with the prime minister, has reintroduced the idea in order to address the challenges annually. The forum is chaired by the president of Rwanda, during which leaders present their achievements and challenges, either economic or social, and any other constructive input they may have about Rwanda as a nation (Turatsinze, 2016).

5.6.3. Home-grown experiences: Case studies

Of the many home-grown experiences, this section reviews three of the more successful ones, in priority development areas. All cases recognized that traditional practices and values, coupled with research and innovation practices, can create sustainable solutions and enhance their impact by adding significant value. Therefore, they are good examples on how the integration of research and innovation policies with other developmental policies are not only possible, but also necessary, to achieve sustainability.

Case study 1: Umuganda

Umuganda is a traditional Rwandan practice and cultural value of working together to solve problems in a shorter time than it would take for an individual to solve them. *Umuganda* embodies the ideas of mutual assistance, mutual social responsibility, social obligation, self-help and traditional strategies for development. In Rwanda, striving for the common good is connected with creating a sense of peace and responsibility in the community.

Umuganda is regarded as crucial for economic and social development, and involves Rwandans between the ages of 18 and 65. Supervision of its implementation is carried out by village leaders, who compare what has been done with what is expected, as it appears in the performance contracts (Barnhart, 2011).

Financially, *Umuganda* is a cornerstone for development, as it contributes significant resources to the country's economy. From 2012–2014, *Umuganda* produced an income of RWF 40 billion, adding a further RWF 9 billion during the first term of 2015. This is due to relief on certain expenses and allowing building infrastructure. In cases of disaster, the practice ensures that the community works together to rebuild destroyed infrastructures. Further, *Umuganda* plays a role in poverty reduction in Rwanda, as it has a direct and indirect impact on households, e.g. by benefiting from the construction of houses for shelter. Schools and other centres of literacy also build houses for the needy as part of their community work. This creates a source of knowledge and skills that encourage innovation.

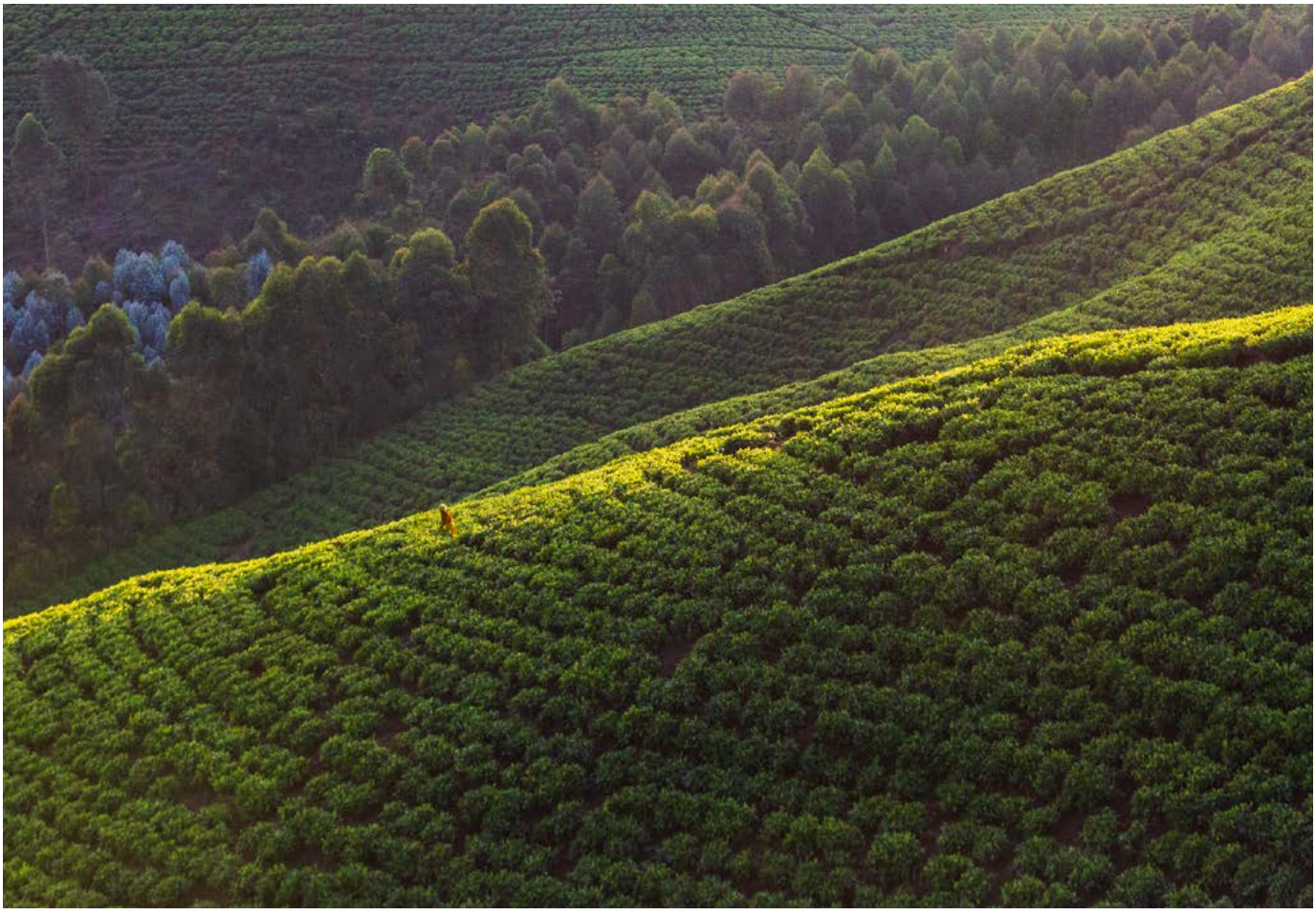


Photo 5.3. Umuganda contributed to finance agriculture that remains the major source of employment for most rwandans but is also impacting total forest area (19,5% in 2017 according to the World Bank).
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Over 400 offices of microfinance institutions, the so-called SACCOs (Savings and Credit Cooperative Organizations), have been built as a result of community work, particularly in the area of agriculture, which is the main source of income for most Rwandans. These institutions help to transform lives and improve communities where they are located, as they instil a saving culture within cooperatives. Cooperatives are poverty reduction engines that drive government policies and programme implementation.

Moreover, *Umuganda* fosters social relations, patriotism and a spirit of self-reliance in Rwandans; it entails sense of togetherness and interaction among community members. Perhaps surprisingly for a country with such a turbulent history, Rwanda has quickly regained its sense of unity. As a result of the country's strong leadership and sensitive reconciliation programmes, Rwanda has managed to understand and honour the identity of its people and make them love their country. As members of the community interact, they share and solve problems with neighbours. Thus, Rwandans expand their solutions to problems on sustainable development through *umuganda*.

This home-grown solution has made Rwanda a role model for other nations. On 25 October 2014, Rwandan peacekeepers under the United Mission in South Sudan built the Kapuri primary school in collaboration with the UN family and local leaders. This inspired other nations to work together for development in a self-reliant and solution-oriented way. *Umuganda* contributes greatly to Rwandan development, especially in the areas of infrastructure and environmental protection. Common infrastructures include roads, bridges, health centres, SACCOs, classrooms (to support the policy of nine and twelve years' basic education), and building houses for vulnerable groups. With regard to environmental protection, projects include tree planting, wetland rehabilitation, renewable energy construction and crop planting. **Table 5.8** below shows the estimated outcomes from community work from 2007 to 2012

In 2009, the Rwandan Government introduced a scheme to reward the best participants in community work, from village to national level, and the best projects were awarded prizes for encouragement. This is known as the national *umuganda* competition. In 2009–2010, all provinces received awards. For instance, Kicukiro district was awarded US$2,000 for the construction of classrooms for nine years' basic education; Nyanza and Muhanga in Southern Province each received US$1,000 for land use consolidation by planting cassava in a farm of 25 ha and for building a canal and pipe system for fresh water, respectively.

Table 5.8. Consolidated value and participation in community works 2007–2012

Year	Participation (people)	Value of activities (RWF)	Technicians
2007	8 638 958	4 112 943 849	n/a
2008	10 772 719	4 852 758 196	n/a
2009	18 342 740	9 451 364 195	n/a
2010	16 165 082	7 980 872 879	36
2010–2011	7 219 508	7 347 720 172	41
2011–2012	18 853 592	12 524 063 160	55
Total	**79 992 599**	**47 269 722 451**	**60**

Source: GoR, 2014.

Case study 2. Rwanda Mutual Health Insurance Scheme

From the 1980s until the 1990s, Rwanda adopted a community-based health insurance scheme, where the rich paid a higher contribution than the poor; this practice later stopped during the genocide war. The insurance system resumed in 1999 as a pilot project and the Government definitively adopted the policy in 2004–2005. This is the insurance used by most of Rwanda's 9.6 million people. Contribution payments depend on a household's *ubudeh* category: 1, 2, 3 or 4. Households in categories 2 or 3 pay RWF 3,000, while those in category 4 (0.5% of the population) pay RWF 7,000 (MoH, 2010). Those in *ubudehe* 1 do not pay anything. The goal of community-based health insurance is to provide Rwandans with an equitable and universal access to quality healthcare service. It also complements other longstanding health insurance schemes within the country.

To reach the insurance scheme's goal, principles are based along the lines of inter sectorial coordination, community participation, decentralization and partnership. In addition, the policy aims to reduce the financial risks associated with disease by social inclusion within the health sector. The policy is backed up by solidarity and equitable principles by increasing the cost of healthcare membership for people in the non-public sector, who are able to get private insurance. The decentralized government encourages health insurance to demonstrate that it is an important indicator of contract performance at the district level. In any case, the decentralized health system increases network health facilities in all districts. So far, the mutual health insurance scheme has emerged as a key driver for Rwanda's sustainable development (MoH, 2010).

Mutual community-based health insurance – *Mutuel de santé* – has reduced mortality and contributed to improvements in the quality of life for children under the age of five and their mothers. Indeed, mothers are encouraged to attend hospital from conception until birth, since healthcare is affordable and the vaccination programmes help to protect them against disease – 70% of mothers now give birth within the healthcare system and services are much improved. The Ministry of Health reports that child mortality dropped from 193 per 1,000 live births to 55 in 2012. In 2014, Rwanda topped the rankings of sub-Saharan countries in the area of healthcare. Since then, the subscription rate for healthcare has increased from 73% in 2013/2014 to 75% in 2014/2015. Rwanda has established 368 healthcare positions, 503 health centres, 42 district hospitals and 5 referral hospitals; SACCO facilitates the subscription charge payment. More amendments are under way in order to achieve universal healthcare coverage.

The management system of community-based health insurance is being strengthened by the Rwanda Health Insurance Council (RHIC) and the Rwanda Social Security Board (RSSB), legally established at the end of July 2015. These improvements are being made by developing a capacity-building plan for community-based health insurance (CBHI), providing sufficient and skilled human resources in different departments within CBHI, training staff from the Ministry of Health, districts and CBHI sections, providing technical assistance, study tours and exchanges between CBHIs, revitalizing CBHI committees in villages, and by strengthening financial and administrative management mechanisms in district CBHIs and sections of CBHI. There is also increasing participation in and ownership of CBHI through sensitization and information dissemination.

Case study 3. Vision Umurenge Programme – VUP

Despite significant efforts to eradicate poverty over recent decades, Rwanda is still ranked as one of Africa's poorest countries. Poverty persists, albeit at a slightly lower rate, as

discussed above. There are multiple factors that contribute to this situation, including: low agricultural productivity, leading to poor major crops; population pressure on arable land; poor agriculture marketing in rural areas; rural unemployment and underemployment; a lack of savings and investment in rural households; and weak environmental conservation practices (GoR, 2007).

These factors are compounded by the enormous social challenges that resulted from Rwanda's turbulent history. The most vulnerable groups are victims of the 1994 genocide war – children who are heads of families, widows and wives, whose husbands are in prison, recently liberated prisoners, unskilled and unemployed youth, landless farmers, the elderly who care for their surviving minor relatives, and wheelchair users.

The GoR has formulated several strategies and initiatives to tackle the issue of extreme poverty. The key strategy is the Vision 2020 Umurenge Programme (VUP) (GoR, 2007). This is an integrated local development programme with a specific focus on the acceleration of poverty eradication, rural growth and social protection. The programme is one of the three flagship programmes of the National Economic Development and Poverty Reduction Strategy (2008–2012), designed to face these challenges. The main aim of the programme is to eradicate extreme poverty by 2020, and its potential is already apparent – the rate of extreme poverty decreased from 36.9% in 2006 to 24% in 2012 (VUP, 2010).

The Umurenge Programme uses the existing decentralization system and leverages technical and financial assistance to accelerate the rate of poverty reduction. It has built on past experiences that show that 'isolated' interventions by sector Ministries, donors and NGOs were not sufficient to lift people out of poverty in a cost-effective and sustainable manner. The other extreme of 'integrated' development has also shown its limitations in many circumstances. One limitation of both isolated and integrated approaches has been the failure to address the two most important economic factors: (i) resources are scarce and (ii) the manner in which people respond to incentives (GoR, 2007).

The VUP is organized around three core components: 1) reviving public work using community-based participatory approaches (e.g. *ubudehe*) to build community assets and create off-farm employment infrastructure; 2) innovating, which is achieved via credit packages to tackle extreme poverty, foster entrepreneurship, and provide off-farm employment opportunities. These packages are designed to make the best possible use of scarce public resources, involve the private financial sector and provide people with incentives to improve their own productive capacities; 3) direct support to improve access to social services, or to provide for landless households, where no members qualify for public work or credit packages. Such unconditional support seeks to expand health and education coverage. It equally encourages the development of 'appropriate' handicraft skills or social service activities, and includes social assistance for extremely vulnerable people.

Umurenge has already had a significant impact. In 2008, public works were the only operational component of the programme, with 18,304 beneficiary households on 38 projects. Between January and June 2009, there were 17,886 beneficiary households on 35 projects. Between July 2009 and June 2010, there were 61,335 beneficiary households on 123 projects, and between July 2010 and June 201, the number of beneficiary households had grown to 70,000 on 226 projects.

Environmental protection projects were the most numerous, consisting mainly of anti-erosive ditches and radical terraces, and growing from 58% of projects in 2008 to 72% in 2009/10. The second most common project type was road reconstruction. Projects have diversified over time – new projects implemented in 2009/10 included the construction of schools, markets, water infrastructure, health centres, improved furnaces, bridges and crop cultivation. Through these projects, one million Rwandans were alleviated from poverty during the period 2008–2012 (see **Table 5.9**).

Table 5.9. Type of public work projects and level of employment.

Public works projects	Amount paid to the workforce (RWF)	Employment generated by gender		
		Women	Men	Total
Road rehabilitation	1 456 998 852	29 773	32 424	62 197
Anti-erosive ditches	1 331 199 217	127 139	119 627	246 766
Reforestation	715 919 520	7 156	3 394	10 550
Radical terraces	1 142 731 831	15 377	12 951	28 328
Classrooms	205 000 000	1 050	856	1 906
Dams	396 731 973	298	282	580
TOTAL	**5 248 681 393**	**180 793**	**169 534**	**350 327**

Source: RLDSF, 2010.

Table 5.9 demonstrates that anti-erosive ditch projects employed the highest number of workers, followed by radical terraces. Dam construction employed the fewest workers; road construction remained the costliest. Women constituted the majority of employed workers. By 30 June 2011, RLDSF had funded a total of 906 development projects, of which 348 were completed and 558 were still ongoing.

The impact that public works have had on Rwanda's infrastructure cannot be understated. Since 2008, 38,350 ha of anti-erosive ditches have been dug, along with 8,611 ha of radical terraces and 594 km of roads. A participant in Gasabo District stated: 'The erosion has decreased in our fields through radical terraces and anti-erosion ditches. Yields, crops and pasture production have increased. Farmers are no longer afraid of their leaders because they want them to visit them, so that they can show them the remarkable change in their standard of living.'

In a similar manner, education has benefited from the construction of 109 classrooms. If the number of projects undertaken in 2008–2009 is compared to those undertaken in 2010–2011, it is clear that public works underwent an exponential growth.

Aside from the financial component of VUP, social changes represent an important achievement. By targeting women, VUP has directly contributed to promotion of gender equality, reversing harmful mindsets against women. Promoting women's economic empowerment through the three components has set a positive example for communities. Furthermore, the use of community mechanisms throughout the process promotes solidarity – a key component for social protection. The relief given to the poor through employment and community engagement has enabled Rwandans to increase their self-esteem and hope for the future (GoR, 2009*b*).

5.7. Conclusions

Rwanda has made substantial progress towards sustainability by implementing a large number of related policies, plans and home-grown initiatives. Today, rapid changes have transformed households' 'livelihoods and created opportunities to forge a more equitable and sustainable future for Rwandan society'.

Photo 5.4. Supporting sustainable, climate resilient livelihoods for poor farming households in Bugesera District

Bizoza (2016) has discussed at length the areas where Rwanda needs to focus to foster sustainability and achieve the SDGs by 2030. He argues that besides strengthening and amplifying its social development programmes – including pertinent educational and capacity-building processes – the role of research and technology development needs to be updated to respond to the needs of policy-makers and to address emerging challenges that call for more technological or social innovation. For example, climate change adaptation and resilience, especially with regard to small-scale farming, will require the support of a strengthened research and innovation system.

Similarly, the impact of home-grown initiatives and case studies such as those described above could certainly be enhanced by engaging a more creative research and innovation system. This could, in part, be achieved by linking and integrating multiple disciplines – i.e. social sciences, science, technology and innovation policies, and a range of knowledge and values systems – thereby increasing the diversity of stakeholders involved in the co-design of the knowledge required to provide solutions to sustainability challenges.

Indigenous and local knowledge (ILK) can play a central role in transforming and modifying technologies to suit local conditions and local contexts when developing home-grown technologies. To do this, indigenous knowledge needs to be documented, protected and efficiently managed. Rwanda needs to incorporate indigenous knowledge in the formulation of research and development strategies – there is scant input from indigenous knowledge systems in current policies and within research programmes. The National Science, Technology, Innovation and Research Policy of 2006 highlights the importance of a research-oriented approach to sustainable and equitable use of resources, prevention of land, water and air degradation, and conservation of biological diversity, to which ILK is a key contributor.

The way forward for Rwanda lies in the clear articulation of integrated issues and priorities, which should be reflected in the needs that have been identified, and consequently be able to develop human resource capacity and build an active, knowledge-based economy. However, the capacity to conduct research is limited, as it is also limited to existing research on understanding the drivers of structural transformation and socio-economic effects on livelihoods, and their role in achieving SDGs (ECA, 2013). This should be underpinned by clearly-identified science and technology capacity needs in policy and plans. To this end, the government of Rwanda co-designed a draft action plan for capacity-building and mobilization in cooperation with UNESCO (2017).

The main priority for the overall operation of Rwanda's research and innovation system is the availability of funding mechanisms. The establishment of FONERWA by the Environment and Climate Change Fund has gone some way to achieving this (CIDT, 2016). Research capacity and system interlinkages need to be invigorated to respond to the needs of policy-makers and to emerging challenges calling for more innovation and the development of sustainability science.

With regard to social and economic development, several other issues need to be addressed through effective policy instruments in order to make the research and innovation system more effective and sustainable. For example, ties between the academic and industry sectors could be strengthened by introducing a demand-pull model at a national scale; extension services and incubators should be more widespread. Furthermore, the private sector needs to be well informed about environment and climate change risks, regulations and opportunities, and civil society empowered to hold government and business to account. While efforts to increase productivity and value addition in the natural resources sectors should be promoted, it is also important to stimulate job creation in other areas, in order to reduce pressure on scarce resources (Drakenberg and Cesar, 2013).

The participation of women in science, research and the innovation agenda-setting process should be mainstreamed into all sectorial programmes and incorporated into the design of specific gender equality policy instruments. Despite the fact that only 20% of researchers are women today, there is no mention of any gender issue, either within the 2005 National STI Policy, or within its 2014 draft revised text. Very few policy interventions have been explicitly planned to change this situation, and there is no single operational policy instrument to promote gender equality within either scientific and technological research activities, or specific incentives to encourage girls and women into STEM.

Rwanda aspires to become a leader in environmental protection, biodiversity conservation and climate change resilience as a platform for green investments embedded in its poverty reduction strategy (EDPRS II). However, there is very little documentation on sustainable natural resources management, biodiversity conservation, climate change science and environmental monitoring and change detection, to deliver on SDG 13 (resilience and adaptive capacity to climate-related natural disasters), and SDG 15 (conservation, restoration and sustainable use of terrestrial and freshwater ecosystem services to enhance capacity to provide benefits for sustainable development). Publications combining more than two SDGs – indicating trans-disciplinary research in the area of sustainability science – are almost non-existent.

Rwanda's vulnerability to climate change will increase rapidly between now and 2050, although socio-economic development may begin to offset the country's growing exposure to climate change later in the 2020s. This implies an urgent need for international scientific cooperation and assistance to conduct transboundary research and finance adaptation measures. Regional and subregional policy interventions are needed to mitigate potential disasters by building research and innovation capacities and promoting the use/adaptation of appropriate technologies in the African context.

Furthermore, Rwanda's reserves of methane, gold, tantalum and other deposits, and its forestry resources are valuable to national development goals, and research is needed on best practices to access these resources safely and sustainably. This should include, for example, the application of geology science for the identification of efficient mine types, and the environmental impacts of new mining or forestry operations in Rwanda.

Several analyses have mentioned that the 2006 STI policy would be updated by 2014; however, this is yet to take place. Although major changes from present policy might not be necessary, the ongoing review is an opportunity to have a more focused, transdisciplinary and inclusive national STI policy to ensure the development of sustainability science as a high national priority.

Photo 5.5. As part of activities marking the entry into force of the Kigali Amendment, guests visiting one of the ten InspiraFarms modular, solar-powered food processing and refrigerated storage facilities that are being set up in six districts across four out of the five provinces of Rwanda.

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RWANDA
East Africa

OVERALL PERFORMANCE

Index score

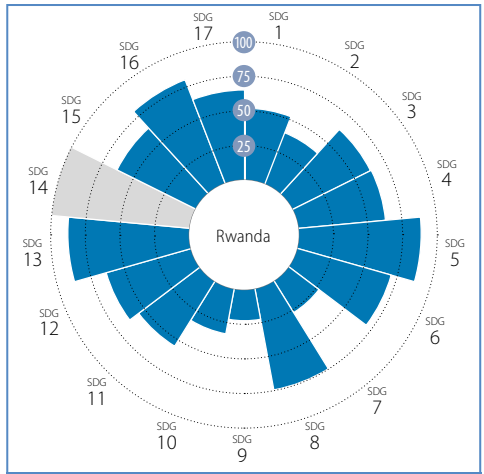
57.9

Regional average score

50.1

Africa Index Rank

11 (OF 51)



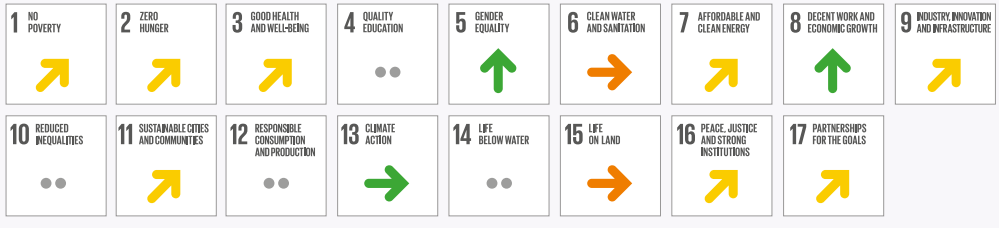
AVERAGE PERFORMANCE BY SDG

COMPARISON WITH OTHER AFRICAN INDICES

	RANK	SCORE
Africa Gender Equality Index (2015)	2 (of 52)	74.3 / 100
Africa Infrastructure Development Index (2016)	26 (of 54)	20.77 / 100
Africa Regional Integration Index (2016)	16 (of 52)	0.55 / 1
Ibrahim Index on African Governance (2017)	9 (of 54)	63.9 / 100

CURRENT ASSESSMENT – SDG DASHBOARD

SDG TRENDS



Notes: The full title of Goal 2 "Zero Hunger" is "End hunger, achieve food security and improved nutrition and promote sustainable agriculture".
The full title of each SDG is available here: https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals

Figure 5.5. Rwanda Country Profile 2018.
The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

RWANDA
Performance by Indicator

SDG1 – End Poverty	Value	Rating	Trend
Poverty headcount ratio at $1.90/day (% population)	45.5	●	↗
Projected poverty headcount ratio at $1.90/day in 2030 (% population)	16.2	●	••
Proportion of population living below the national poverty line	44.9	●	••
Population covered by Social Protection (%)	35.3	●	••

SDG2 – Zero Hunger	Value	Rating	Trend
Prevalence of undernourishment (% population)	41.1	●	••
Prevalence of stunting (low height-for-age) in children under 5 years of age (%)	44.3	●	↗
Prevalence of wasting in children under 5 years of age (%)	3.0	●	→
Prevalence of obesity, BMI ≥ 30 (% adult population)	5.8	●	→
Cereal yield (t/ha)	1.5	●	↓
Fertilizer consumption (kg per hectare of arable land)	19.7	●	↑

SDG3 – Good Health and Well-Being	Value	Rating	Trend
Maternal mortality rate (per 100,000 live births)	290.0	●	↑
Births attended by skilled health personnel (%)	90.7	●	••
Neonatal mortality rate (per 1,000 live births)	16.5	●	↑
Mortality rate, under-5 (per 1,000 live births)	38.5	●	↑
HIV prevalence (per 1,000)	0.2	●	↑
People living with HIV receiving antiretroviral therapy (%)	80.0	●	••
Incidence of tuberculosis (per 100,000 people)	50.0	●	↑
Proportion of children under 5 with fever who are treated with appropriate anti-malarial drugs (%)	12.0	●	••
Malaria mortality rate	33.6	●	↗
Coverage of Preventive Chemotherapy for Neglected Tropical Diseases (%)	84.4	●	••
Age-standardised death rate due to cardiovascular disease, cancer, diabetes, and chronic respiratory disease in populations age 30–70 years (per 100,000 population)	20.4	●	→
Traffic deaths rate (per 100,000 people)	32.9	●	↓
Adolescent fertility rate (births per 1,000 women ages 15-19)	26.8	●	↑
Universal Health Coverage Tracer Index (0-100)	52.4	●	→
Age-standardised death rate attributable to household air pollution and ambient air pollution (per 100,000 population)	142.1	●	••
Percentage of surviving infants who received 2 WHO-recommended vaccines (%)	95.0	●	→
Healthy Life Expectancy at birth (years)	66.1	●	↑
Subjective Wellbeing (average ladder score, 0-10)	3.3	●	↓

SDG4 – Quality Education	Value	Rating	Trend
Net primary enrolment rate (%)	95.9	●	••
Mean years of schooling (years)	3.8	●	→
Literacy rate of 15-24 year olds, both sexes (%)	82.3	●	••

SDG5 – Gender Equality	Value	Rating	Trend
Proportion of women aged 20-24 years who were married or in a union before age 18	6.8	●	••
Proportion of girls and women aged 15-49 years who have undergone female genital mutilation/cutting, by age	0.0	●	••
Seats held by women in national parliaments (%)	61.3	●	→
Women in ministerial positions (%)	47.4	●	••
Estimated demand for contraception that is unmet (% women married or in union, ages 15-49)	24.6	●	↑
Ratio of female to male mean years of schooling of population age 25 and above (%)	75.0	●	••
Ratio of female to male labour force participation rate	99.7	●	→

SDG6 – Clean Water and Sanitation	Value	Rating	Trend
Population using at least basic drinking water services (%)	56.7	●	→
Population using at least basic sanitation services (%)	62.3	●	↗
Freshwater withdrawal as % total renewable water resources	1.4	●	••
Imported groundwater depletion (m^3/year/capita)	2.3	●	••

SDG7 – Affordable and Clean Energy	Value	Rating	Trend
Access to electricity (% population)	19.8	●	↗
Access to clean fuels & technology for cooking (% population)	2.0	●	→
Renewable energy share in the total final energy consumption	88.4	●	→
Consumer affordability of electricity	0.0	●	••

SDG8 – Decent Work and Economic Growth	Value	Rating	Trend
5-year average GDP growth per capita (%)	4.5	●	••
Employment-to-population ratio	82.7	●	→
Slavery score (0-100)	50.0	●	••
Adults (15 years and older) with an account at a bank or other financial institution or with a mobile-money-service provider (%)	50.0	●	↑
Starting a Business score	87.7	●	→

SDG9 – Industry, Innovation and Infrastructure	Value	Rating	Trend
Infrastructure score (0-100)	45.3	●	••
Logistics performance index: Quality of trade and transport-related infrastructure (1=low to 5=high)	2.6	●	••
Research and development expenditure (% GDP)	0.0	●	••
Number of scientific and technical journal articles (per 1,000)	0.0	●	••
Mobile broadband subscriptions (per 100 inhabitants)	28.9	●	↑
Proportion of the population using the internet (%)	20.0	●	→

SDG10 – Reduced Inequalities	Value	Rating	Trend
Gini Coefficient adjusted for top income (1-100)	53.3	●	••

SDG11 – Sustainable Cities and Communities	Value	Rating	Trend
Proportion of urban population living in slums	53.2	●	••
Improved water source, piped (% urban population with access)	72.6	●	→
Satisfaction with public transport (%)	60.0	●	↑
Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5) in urban areas (µg/m^3)	49.7	●	↓

SDG12 – Responsible Consumption and Production	Value	Rating	Trend
Municipal Solid Waste (kg/year/capita)	0.5	●	••
E-waste generated (kg/capita)	0.6	●	••
Natural Resource Value Realization Score	NA	●	••
Production-based SO_2 emissions (kg/capita)	1.1	●	••
Anthropogenic wastewater that receives treatment (%)	0.0	●	••
Net imported SO_2 emissions (kg/capita)	0.6	●	••

SDG13 – Climate Action	Value	Rating	Trend
Climate Change Vulnerability Monitor (best 0-1 worst)	0.2	●	••
Energy-related CO_2 emissions per capita (tCO_2/capita)	0.1	●	→
Imported CO_2 emissions, technology-adjusted (tCO_2/capita)	0.1	●	••
CO_2 emissions embodied in fossil fuel exports (kg/capita)	0.0	●	••

SDG14 – Life Below Water	Value	Rating	Trend
Percentage of inadequately managed plastic waste	NA	●	••
Ocean Health Index Goal - Clean Waters (0-100)	NA	●	••
Ocean Health Index Goal - Biodiversity (0-100)	NA	●	••
Ocean Health Index Goal - Fisheries (0-100)	NA	●	••
Mean area that is protected in marine sites important to biodiversity (%)	NA	●	••
Percentage of Fish Stocks overexploited or collapsed by EEZ (%)	NA	●	••
Fish caught by trawling (%)	NA	●	••

SDG15 – Life on Land	Value	Rating	Trend
Mean area that is protected in terrestrial sites important to biodiversity (%)	45.7	●	→
Percentage change in forest area (2010-2015)	1.4	●	••
Red List Index of species survival (0-1)	0.9	●	→
Imported biodiversity threats (threats/capita)	1.2	●	••

SDG16 – Peace, Justice and Strong Institutions	Value	Rating	Trend
Homicides (per 100,000 people)	4.5	●	••
Conflict-related deaths per 100,000	0.0	●	→
Proportion of the population who feel safe walking alone at night in the city or area where they live (%)	87.0	●	→
Children 5–14 years old involved in child labour (%)	28.5	●	••
Property Rights (0-100)	75.1	●	→
Access to justice (0-100)	82.8	●	↓
Corruption Perception Index (0-100)	55	●	↗
Public Sector Accountability & Transparency (0-100)	85.5	●	↑
Birth registrations with civil authority, children under 5 years of age (%)	56	●	••

SDG17 – Partnerships for the Goals	Value	Rating	Trend
Tax revenue (% GDP)	19.3	●	↗
Government Health and Education spending (% GDP)	12.7	●	••
Level of customs duties on imports	33.5	●	••
Visa Requirement score	48.0	●	••
Governmental Statistical Capacity	77.8	●	↑

Figure 5.6. Rwanda performance by indicator.

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

References

Barnhart, J. 2011. Umuganda: The ultimate nation-building project? *Pursuit – The Journal of Undergraduate Research*, Vol. 2, No. 1. Retrieved from: http://trace.tennessee.edu/pursuit/vol2/iss1/3

Bizoza, A. R. 2016. Where Rwanda needs to focus on in the new course of Sustainable Development Goals by 2030? Institute of Policy Analysis and Research (IPAR). Available at: http://www.chronicpovertynetwork.org/blog/2016/3/3/sdgs-series-1-where-rwanda-needs-to-focus-on-in-the-new-course-of-sustainable-development-goals-by-2030

CIA. 2017. *CIA World Fact Book 2017*. New York, Skyhorse Publishing.

CIDT. 2016. *Creation of the National Fund for Climate and Environment (FONERWA): Support to the Fund Management Team*. Retrieved from www.cidt.org.uk

Drakenberg, O. and Cesar, E. 2013. Environment and climate change policy brief – Rwanda, final draft. IDA Helpdesk for Environment and Climate Change. Available at: www.sidaenvironmenthelpdesk.se

EC. 2006. *The Environmental Profile of Rwanda*. Kigali, European Commission.

ECA. 2013. *Economic Transformation for Africa's Development*. Addis Ababa, UN Economic Commission for Africa.

Farley, S., Rose, A. L., Gerard, A. and Safari, J. P. 2013. *Review of Rwanda's National STI Policy and Recommendations for Strategy.* Kigali, Global Knowledge Initiative.

FONERWA. 2012. *National Fund for the Environment,* Kigali, Rwanda Environmental Agency.

Fortune of Africa. 2017. Challenges facing education sector in Rwanda. Fortune of Africa website. Retrieved January 31, 2017.http://fortuneofafrica.com/rwanda/challenges-facing-education-sector-in-rwanda/

Future Earth. n.d. Knowledge-action networks. http://futureearth.org/knowledge-action-networks

GoR. 2000. *Rwanda Vision 2020*. Kigali, Ministry of Finance and Economic Planning.

GoR. 2003. *Rwanda Environmental Policy*. Kigali, Ministry of Lands, Resettlements and Environment.

GoR. 2005. Organic law determining the modalities of protection, conservation and promotion of the environment in Rwanda. *Official Gazette of the Republic of Rwanda* No. 04, 8 April.

GoR. 2006. *The Republic of Rwanda Policy on Science, Technology and Innovation*. Kigali, State Ministry in the President's Office in Charge of Science, Technology and Scientific Research.

GoR. 2007. *Vision 2020 Umurenge: An Integrated Local Development Programme to Accelerate Poverty Eradication, Rural Growth, and Social Protection*. Kigali, Government of Rwanda.

GoR. 2009*a*. *Law on the Protection of Intellectual Property*. Kigali, Government of Rwanda. http://www.minicom.gov.rw/fileadmin/minicom_publications/law_and_regurations/Law_on_the_protection_of_intellectual_property.pdf

GoR. 2009*b*. *Vision 2020 Umurenge Programme, Public Works Operational Framework and Procedure Manual*. Kigali, Ministry of Local Government.

GoR. 2011. *Rwanda National Strategy on Climate Change and Low Carbon Development.* Kigali, Ministry of Natural Resources.

GoR. 2012*a*. *Science and Technology in Rwanda*. Paper presented to the 27th Annual Meeting of the Third World Academy of Sciences. Kigali, Government of Rwanda.

GoR. 2012*b*. *Itorero Ry'Igihugu Strategic Plan 2009–2012, Making National and Community Service*. Kigali, Government of Rwanda.

GoR. 2013. *Economic Development and Poverty Reduction Strategy II 2013–2018*. Kigali, Ministry of Finance and Economic Planning.

GoR. 2014*a*. *SMART Rwanda Master Plan 2015–2020: A Prosperous and Knowledgeable Society through SMART ICT*. Kigali, Government of Rwanda.

GoR. 2014*b*.Umuganda concept note on current status. Kigali, MINALOC.

GoR. 2016*a*. *Rwanda's Approach to Implementing the SDGs*. Conference on Regional Solutions to Achieve SDGs. Ministry of Finance and Economic Planning, Kigali, 26 April.

GoR. 2016*b*. *Smart Rwanda Master Plan*. Presentation paper. Ministry of Youth and ICT. https://www.theigc.org/wp-content/uploads/2016/11/Session-4.2-RMP_Mineacom.pdf

HECR. 2016. *Final Report on Ranking of Higher Education Institutions in Rwanda*. Kigali, Higher Education Council of Rwanda.

Hughes, M. and Gasore, J. 2014. *The Rwanda Climate Observatory Project*. Kigali, CAAST-Net Plus Regional Workshop, May 28–30.

IMF. 2018. *IMF Review Mission Report to Rwanda*. Washington DC, IMF.

IPU. 2017. *Women in Politics 2017 Map* (as of 1 January 2017). World Classification, Inter-parliamentary Union and UN Women. Retrieved 12 April 2018 http://www.ipu.org/wmn-e/classif.html

MoH. 2010. *Rwanda Community-based Health Insurance Policy*. Kigali, Ministry of Health.

NISR. 2016*a*. *Statistical Yearbook.* Kigali, National Institute of Statistics of Rwanda.

NISR. 2016*b*. *Poverty Trend Analysis Report 2010/11.* Kigali, National Institute of Statistics of Rwanda.

NISR. 2012. *Comprehensive Food Security and Vulnerability Analysis – 2012*. Kigali, National Institute of Statistics of Rwanda. www.statistics.gov.rw/datasource/94

REMA. 2015*a*. *Rwanda, State of Environment and Outlook Report*. Kigali, Rwanda Environmental Management Authority. https://doi.org/10.13140/RG.2.1.5148.6328

REMA. 2015*b*. *A Toolkit for the Development of Smart Green Villages in Rwanda*. Kigali, Rwanda Environmental Management Authority.

REMA. 2017. *Rwanda: Top 10 Environment Milestones for 2016*. Kigali, Rwanda Environmental Management Authority.

RGB. 2014. *The Assessment of the Impact of Home Grown Initiatives*. Special Issue IV. Kigali, Rwanda Governance Board.

RLDSF. 2010. *Rwanda Local Development Support Fund, Annual report 2009–2010*.

Shah, P. P. 2011. Girls' education and discursive spaces for empowerment: Perspectives from rural India. *Research in Comparative and International Education,* Vol. 6. Retrieved from www.wwwords.uk/RCIE

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network. Available at http://africasdgindex.org

Turatsinze, J. 2016. *The Formula for Accelerated Change VxP2xAxT=C . How to Become a Visionary Leader, Achieve Success and Sustainable Development*. CreateSpace Independent Publishing Platform.

UN Women. 2016. Women and Sustainable Development Goals. *UNICEF Malaysia Communications*, pp. 1–32. http://doi.org/10.1108/eb010586

UNCTAD. 2017. *Science, Technology & Innovation Policy Review: Rwanda, Geneva and Kigali*. United Nations Conference on Trade and Development.

UNDP. 2008. Country context. *Assessment of Development Results: Rwanda*. UNDP. Available at: http://web.undp.org/evaluation/evaluations/adr/rwanda.shtml

UNDP. 2017. *Human Development Index (HDI) | Human Development Reports*. Retrieved February 17 2017 from http://hdr.undp.org/en/content/human-development-index-hdi

UNEP. 2009. *Rwanda: State of the Environment and Outlook*. Nairobi, United Nations Environmental Programme.

UNEP. 2011. *Cities: Report on Investing in Energy and Resource Efficiency.* Nairobi, United Nations Environmental Programme.

UNESCO. 2015. Mapping research and innovation in the Republic of Rwanda. G. A. Lemarchand and A. Tash (eds), *UNESCO GO→SPIN Country Profiles in Science, Technology and Innovation Policy,* Vol. 4. Paris, UNESCO.

UNESCO. 2017. *UNESCO Science Report. Evaluation of the UNESCO Science Report – Towards 2030*. Paris, IOS Evaluation Office.

VUP. 2010. *Vision 2020 Umurenge Programme Annual Report*. Kigali, Minstry of Local Government.

WEF. 2016. *World Economic Forum on Africa*. Kigali, WEF.

WHO. 2001. *Legal Status of Traditional Medicine and Complementary/Alternative Medicine: A Worldwide Review*. Essential Medicines and Health Products Information Portal: A World Health Organization Resource, 200. Available at: http://doi.org/j

World Bank. 2017. *Rwanda Overview*. World Bank. Retrieved January 30, 2017. http://www.worldbank.org/en/country/rwanda/overview

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6

Constructing sustainability science in Tanzania

6. Constructing sustainability science in Tanzania

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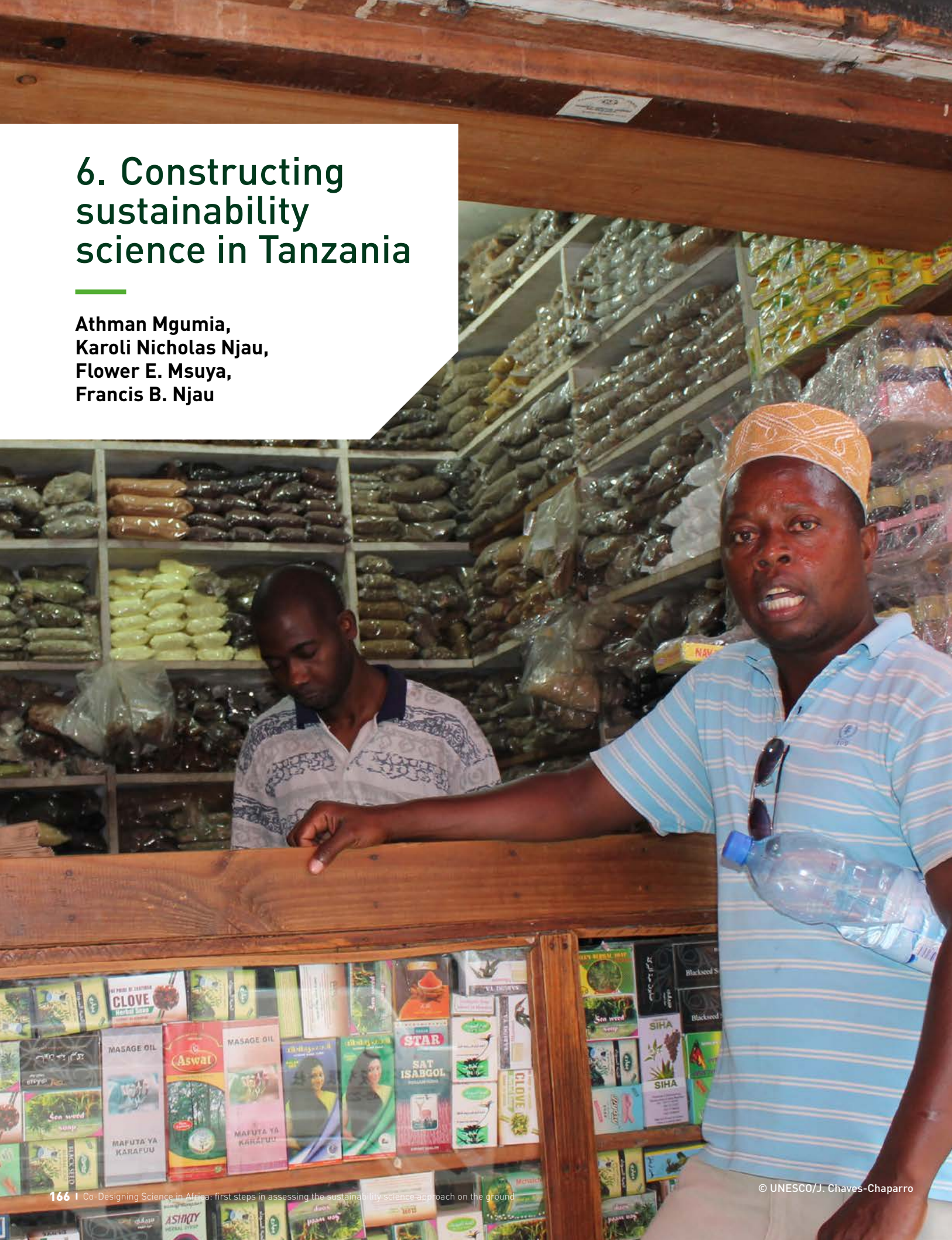

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6.1. Introduction

The United Republic of Tanzania (URT) in eastern Africa occupies a territory of 947,300km^2. It has a population of 54 million people, composed of multiple ethnic groups, with a majority of Bantu origin. The population also includes Asian and expatriate minorities. The people of Zanzibar are of Bantu, Persian and Arab origin. This demographic mix, living in peaceful coexistence, presents a positive example of development in Africa.

Tanzania is one of a handful of African countries that have enjoyed continuous political stability since independence in 1961. As noted in Deloitte's 2017 report, this situation, together with recent steps taken by government to eradicate corruption, has provided an enabling economic context throughout the years. Ngowi's 2009 study points out that economic development and change in the country can be mostly attributed to satisfactory political leadership.

In recent decades, Tanzania has observed sustained economic growth as well as some success in its poverty reduction strategy and other social reforms. These were the result of the adoption and implementation of the National Strategy for Growth and Reduction of Poverty (MKUKUTA I and II) (URT, 2010*a*), which followed the guidelines provided by the National Development Vision 2025 (URT, 2000). The strategy was built on key fundamentals closely related to the performance of the national innovation system: the efficient use and development of production factors that include human capital/resources; the strengthening and establishment of well-functioning institutions and markets; and the adoption of a strengthened economic governance.

To complement the different measures envisioned in Vision 2025, a number of policies were developed for specific sectors, including the National Research and Development Policy of 2010, the National Agricultural Policy of 2013 and the Biotechnology Policy of 2010. All these policies aim in one way or the other to build capacities for sustainable development in Tanzania.

Several of the existing economic and social problems in Tanzania today are caused by environmental challenges that need to be faced. The country is aware of such challenges, understanding at the same time that problems related to economic and social issues, for example population growth and availability or otherwise of improved technologies, also have a large impact on sustainability.

This chapter will give a brief review of the economic and social situation of Tanzania in section 2, while describing sustainability challenges in section 3 and policies adopted to face these challenges in section 4. Section 5 will describe the national innovation system, including the adopted policies, strategies and different institutional arrangements. Finally, section 6 will show, through selected case studies, how local research and innovation capacities are being mobilized for sustainable development.

6.2. Socio-economic overview

6.2.1. The economic context

Tanzania has been able to make important economic and structural reforms to sustain its economic growth, becoming one of the fastest-growing economies in Africa during the present decade, and the highest-ranked in the East African Community (EAC) in 2017, despite a slower growth rate, mainly attributed to a slowdown of services from the supply side and a slower expansion of consumption and investment from the demand side.

Between 2010 and 2016, GDP grew by over 6.9% per year and is expected to grow at an average of 6.2% between 2017 and 2026. This growth is underpinned by infrastructure development, especially in telecommunications, and a growing consumer base (Deloitte and Touche, 2017). Population growth, coupled with an urbanization rate of around 30% in the past ten years, has resulted in an increased consumer and credit demand. However, as the country is basically a commodities exporter and a net importer of oil, the Tanzanian economy is not immune to external shocks.

It is estimated that by 2017, services will have contributed 47.6% to GDP, industry 28.6% and agriculture 23.8% (CIA, 2018). Agriculture remains the largest employer, accounting for 66.3% of the workforce (URT, 2015). Despite being a frontrunner in economic growth, Tanzania shares many similarities with other countries in the subregion, including the relatively slow pace of industrialization.

The future economic outlook is favourable, with downside risks that are largely under government control. The three most significant challenges facing the government to ensure the growth momentum include:

- Continuing to implement measures to ensure macroeconomic stability;
- Intensifying efforts to implement its development-oriented budget; and
- Urgently implementing measures to enable and encourage the private sector to play a more significant role in Tanzania's development (World Bank, 2018).

Private sector involvement in the country's development must support the government's ambitious investment plans, be a source of finance and innovation, and create jobs for new entrants into the job market. To promote private sector participation in the economy, several key impediments, such as low credit growth, high and persistent payment arrears, and the high cost of regulatory compliance and deficiencies in infrastructure services and skills, must be overcome. Two key economic sectors are briefly described below.

Energy

The Tanzania power sector is characterized by a low electrification rate. By fuel source in the period 2011–2014, biomass is the main source of primary energy (90%) (REN21, 2016) while hydroelectricity contributes only 1.5%, petroleum products 8.0% and others 0.5%. The electrification rate in Tanzania grew from 15% in 2010 to 24% in 2013, the highest in East Africa, while the access target is 50% in 2025. In general, the rural electrification rate is significantly lower than the urban one. The problems of intermittent power supply, low voltage, frequent rationing and outages are among the constraints that affect the production of goods and services in Tanzania. The Tanzania Electric Supply Company (TANESCO), owned entirely by the government, focuses mainly on electricity generation, transmission and distribution. TANESCO provides approximately 60% of the generating capacity of Tanzania's national grid. By 2014, Tanzania had a total hydropower capacity of 562 MW, including 12 MW of small-scale hydropower.

In spite of their potential availability, the commercial exploitation of alternative energy sources, such as minihydro, wind, biogas, solar and geothermal, has been slow.

Tanzania established its Domestic Biogas Programme, with the installation of more than 12,000 biogas plants, between 2009 and 2015. With the discovery of large deposits of natural gas along the coast of the Indian Ocean both onshore and offshore in recent years, Tanzania intends to reduce the country's dependence on hydropower and to diversify its energy supply with an additional 4,000 MW of natural gas capacity and 2,900 MW of coal capacity by 2025. (REN21, 2016).

The institutional set-up and actors in the energy sector include the Ministry of Energy and Minerals (MEM), through which government formulates its energy policy. Recently adopted electricity act focuses on restructuring the electricity supply industry – attracting private sector and other participation, thus ending the TANESCO monopoly. At present the Electricity Sector Act provides separate licences for generation, transmission and distribution. The Energy and Water Utility Regulatory Authority (EWURA) is responsible for technical and economic regulation of electricity, petroleum, natural gas and water. The Rural Energy Agency (REA) is responsible for boosting modern energy services in rural areas.

Transport

The railway transport system is comprised of Tanzania Railways Limited (TRL) and the Tanzania and Zambia Railway Authority (TAZARA), serving 14 of the 26 regions of Tanzania's mainland. At the same time, Tanzania has established itself as a crucial national and international trade gateway, and air transport plays an important role in the economy, particularly in the tourism sector and horticultural exports.

Challenges in transport include: inadequate integration of the road network, markets and productive areas; inadequate investment in the maintenance and rehabilitation of railways; inadequate exploitation of the potential of marine transport to meet domestic, regional and international demands; and the need for improved and adequately maintained air transport facilities and services. The government needs to focus on the improvement of infrastructure, which has a bearing on growth and development. Infrastructure improvement should aim to take advantage of the country's strategic role as a hub for a number of eastern, central and southern African countries.

Photo 6.1. Zanzibar promotes an integrated approach to the environmental dimension of sustainable development, led by the Ministry of Lands, Water, Energy and Environment.
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6.2.2. The social context

The current Five-Year Development Plan II (FYDP 2016–2021), built on subsequent national strategies of MKUKUTA II (Strategy for Growth and the Reduction of Poverty), MKUZA II and III (Strategy for Growth and the Reduction of Poverty in Zanzibar) and FYDP I, has recognized the immense social challenges that

the country faces in the future, in spite of important progress made during past decades. In fact, as a result, Tanzania's Human Development Index value increased from 0.371 in 1985 to 0.521 in 2014.

As analysed by the latest World Bank study (World Bank, 2018), poverty has declined since 2007 and continues to drop at a modest pace, with a fall in the poverty rate from 28.2% in 2012 to 26.9% in 2016. Despite this decrease, the absolute number of poor has not reduced because of the high population growth rate – more than 13 million people remained below the poverty line in 2016 (World Bank, 2016*a*).

The decline in the poverty rate was accompanied by improvements in living conditions; the ownership of assets and access to clean drinking water and sanitation, including for poor and rural populations; access to basic education, health and nutrition; and the participation of the labour force in non-agricultural employment. These benefits were not distributed equitably, however. Inequality increased between the urban and rural population. The poverty headcount is only 4.1% of the population in Dar es Salaam, compared with 33.3% in rural areas (URT, 2015). This steady increase in spatial inequality is a phenomenon shared with most other east African states.

Education

In primary education, levels of access, completion and equity improved during the period 2010–2016, as did levels of secondary educational attainment for both women and men. In 2016, 23.4% of women and 28.2% of men had completed secondary education, a significant increase from the figures of 16.2% and 22.8% recorded in 2010.

The primary net enrolment rate stands at 98% and the primary completion rate is 81% (IBRD/World Bank, 2014), with gender parity. Both indicators provide a sense of the country's progress towards universal primary education. Available data show that the net enrolment rate in secondary schools has steadily increased from 30.64% in 2010 to 33.65% in 2012 but experienced a drop to 31.67% in 2013.[1] Higher education has expanded, with an enrolment rate of 3.92% in 2015 from 2.12% in 2010. This sector will be described further in section 5.

Challenges in education include improving the supply, capacities and working conditions of teachers and quality and availability of learning resources, alongside the expansion of education infrastructure and other implicit interventions, such as improving roads/access to schools. Of particular importance is the need to improve the quality of education, which depends on an increase in the equitable deployment of qualified teachers and resources to all areas of the country.

Health and sanitation

Improved health outcomes have been one of the key drivers of progress in the rate of poverty reduction, along with robust gains in education and incomes. Notably between 1980 and 2014, life expectancy at birth increased by 14.5 years; expected years of schooling increased by 3.3 years. Infant mortality also declined from 68 deaths per 1,000 live births in 2005 to 41 in 2012/13.

Lower maternal and infant mortality rates were reported between 2005 and 2015. The maternal mortality rate dropped from 687 to 318 per 100,000 live births, while the neo-natal mortality rate decreased from 28.1 to 21.7 per 1,000 births. The under-five mortality rate decreased from 93.7 to 58.8 per 1,000 live births in that period.

There is also evidence of outbreaks of cholera, incidences of tuberculosis, and widespread malnutrition. Furthermore, communicable and other diseases, such as HIV/AIDS and malaria, as well as diarrhoea, pneumonia, malnutrition and complications of low birth weight, continue to overburden the health sector. Noncommunicable diseases (NCDs), such as cancer and cardiovascular disease, currently account for the highest number of deaths and their prevalence has been rising. For example, according to WHO, NCDs are estimated to account for 31% of total deaths (WHO, 2014).

Overall access to improved sanitation increased from 12.2% to 15.6% between 2008 and 2015.The increase of unplanned settlements has intensified the challenge of increasing access to environmental sanitation and hygiene services for urban dwellers. It is estimated that only 34.2% of the urban population have access to improved sanitation, with the remainder using very basic sanitation facilities (URT, 2014*a*).

Although 90% of people have access to primary healthcare facilities within five kilometres of the larger cities (see, for example, World Bank, 2016*b*), the limited quality of health services has undermined health parameters. In addition, inadequate enforcement of health policies, such as free health services that aim to support special groups including pregnant women, children and elders, has undermined health outcomes and reduced life expectancy to 66.7 years (UNDP, 2017).

Urban development

Unplanned settlements have been increasing and include developments in hazard-prone areas such as steep slopes, floodplains, river valleys and dumpsites (URT, 2010*b*). It is

1 http://uis.unesco.org/country/TZ

estimated that by the year 2030, 50% of the national population will be urbanized through natural growth, inward migration and transformation of rural settlements into urban centres. Rural to urban migration is eroding rural labour, while at the same time migrants scramble for the limited employment opportunities in towns. Migration also exerts pressure on the existing social and physical infrastructure, as well as increasing social security risks in urban centres. Among these is urban sprawl, which exacerbates the existing problems of inefficient urban public transport and waste management, and poor levels of hygiene.

Programmes for sustainable cities and safer cities currently being implemented (specifically in Dar es Salaam) seem not to adequately address the challenge of urbanization. These also need to be further examined, since they affect resource use and thus have direct environmental consequences.

Housing is a challenge to all urban and rural settlements in terms of both quality and quantity. Housing finance has long been a pertinent issue. Alternative low-cost building materials and building technologies have not been adequately addressed in terms of research and construction. While rural areas are faced more with the poor quality of houses, in towns housing shortages and poor hygiene prevail, especially in unplanned settlements.

Gender

Tanzanian women and girls remain among the most marginalized and underutilized citizens in sub-Saharan Africa (USAID, 2018). In fact, the Gender Related Development Index (GDI)[2] ranks the country in 127th place out of 140 (Country Watch, 2018). **Table 6.1** provides some of the main indicators measuring the status of women in the country.

Given that enabling gender equality and empowering women are both critical factors for the advance of progress and growth in the country, the government has adopted policies to encourage gender equality and youth inclusion in a supportive, enabling environment. The legal and regulatory frameworks and the sector-specific policies of government ministries and independent departments, however, have yet to be aligned with these policies.

Table 6.1. Status of women in Tanzania: Selected indicators

Indicator	Value
Gender empowerment measure (GEM) rank[1]	42nd out of 80
Female life expectancy at birth	52 years
Total fertility rate	5.3
Maternal mortality ratio (2000)[2]	1 500
Total number of women living with HIV/AIDS:	640 000–780 000
Married Women, aged 15-19	25%
Mean age at time of marriage	21
Contraceptive use among married women, any method	25%
Female adult literacy rate	65% (overall population literacy rate is 70%)
Combined female gross enrolment ratio for primary, secondary and tertiary schools	40%
Female-headed households	23%
Economically-active females[3]	81.4%
Seats in parliament held by women: Lower or Single House	21.4%
Year women received the right to vote and the right to stand for election: 1959	1959

[1] The Gender Empowerment Measure (GEM) is a composite index measuring gender inequality in three of the basic dimensions of empowerment: economic participation and decision-making; political participation and decision-making; and power over economic resources.
[2] The maternal mortality rate is the number of deaths in women per 100,000 live births that result from conditions related to pregnancy and/or delivery-related complications.
[3] 'Economically-active females' refers to the share of the female population, aged 15 and above, who supply, or are able to supply, labour for the production of goods and services.

Source: Country Watch, 2018.

Photo 6.2 Although more than 80% of Tanzanian women are economically active, they remain among the most marginalized of Africa in terms of political participation and decision making as well as power over economic resources. Banana Investment Limited company in Arusha (Tanzania)
© UNESCO/J. Chaves-Chaparro

Several bilateral and multilateral cooperation agencies have also advanced a number of actions to deal with existing critical problems, thus allowing Tanzanian women and girls to have greater access to and control over resources, opportunities and decision-making power, in order to sustainably reduce extreme poverty, build healthy communities and promote inclusive growth.

One such example is Project Tumaini ('Hope'), which serves the critical unifying role of integrating gender equality, women's

empowerment and youth inclusion across a broad range of USAID activities (USAID, 2018). This project encompasses activities focused on youth empowerment in agriculture, providing friendly and accessible health services, ensuring girls enrol in and complete secondary school, and integrating human rights and social inclusion programming.

On the other hand, several studies imply that 'gender equality and the empowerment of women are unattainable or that they are unimportant' (Simmonds, 2014, p. 636), suggesting a patriarchal dominance within African culture, from which Tanzania does not escape. Walby (1990) claims that throughout education, gender roles are encouraged through not only the formal curriculum but also the hidden curriculum. This is where children commonly pick things up informally and subconsciously regarding gender roles, encouraging feminine and masculine behaviours.

In her analysis of gender issues in education in Tanzania, Weatherston (2017) shows that gender inequality is still very prevalent within education in Tanzania and is encouraged within everyday routines and throughout education, much in line with Walby's views. Throughout her research, it is also highlighted that poverty is one of the major factors and underlying issues encouraging gender inequalities within education, with many girls being pushed into marriage as a means of a quick but temporary solution to poverty. This finding strongly suggests the need to explore the effects of poverty on gender equality and the attitudes of people within the wider community.

6.2.3. Vision 2025

The National Development Vision 2025 (URT, 2000) envisions that Tanzania will have graduated from a least-developed country to a middle-income country by the year 2025, with a high level of human development. The economy will have been transformed from a low-productivity agricultural economy to a semi-industrialized one led by modernized and highly productive agricultural activities that are effectively integrated and buttressed by industry and services in rural and urban areas. A solid foundation for a competitive and dynamic economy with high productivity will have been laid. Consistent with this vision, the Tanzania of 2025 should be a nation imbued with six main attributes:

1. High-quality livelihoods: the creation of wealth and its distribution in society must be equitable and free from inequalities and all forms of social and political relations which inhibit empowerment and effective democratic and popular participation of social groups (men and women, boys and girls, the young and old, the able-bodied and disabled persons) in society.
2. Peace, stability and unity: the country should enjoy peace, political stability, national unity and social cohesion in an environment of democracy and political and social tolerance.
3. Good governance should permeate the national socio-economic structure, thereby ensuring a culture of accountability, rewarding good performance and effectively curbing corruption and other vices in society.
4. A well-educated and learning society, where people are ingrained with a developmental mindset and competitive spirit. In order to achieve this, Tanzania should attain self-reliance and create a sense of ownership of its development agenda; foster a positive mindset and a culture which cherishes human development through hard work, professionalism, entrepreneurship, creativity, innovativeness and ingenuity; and have a high quality of education at all levels, producing the desired quantity and quality of sufficiently educated people.
5. With the required knowledge to solve society's problems, the country will be ready to meet the challenges of development and attain competitiveness at regional and global levels.
6. A competitive economy: a strong, diversified, resilient and competitive economy which can effectively cope with the challenges of development and which can also easily and confidently adapt to the changing market and technological conditions in the regional and global economy.

Vision 2025 has exerted a consistent influence on – and a direct inspiration for – several government initiatives. Of particular interest in this study is the recognition of the importance of environment and sustainable development, although at the time of its publication, clearly-defined ways forward were not fully incorporated.

6.3. Main sustainability challenges

The National Environmental Policy (URT, 1997) identifies six major sustainability problems: 1) loss of wildlife habitats and biodiversity; 2) deforestation; 3) land degradation; 4) deterioration of aquatic systems; 5) lack of accessible, good quality water; and 6) environmental pollution.

As noted by Assey et al. (2007, p.6), the 1997 National Environment Policy (NEP) was seminal in identifying the major environmental problems facing Tanzania. However, this list of problems, although very informative 10 years ago, has been continually repeated in most official and NGO documentation

up to the present day. Assey et al. find this 'triply disturbing. Firstly, because these problems have not yet lessened but are getting worse – most notably drought and deforestation; secondly, because further problems such as climate change and the extensive environmental pressures of refugee settlements are emerging, and yet the list remains static; thirdly, because the way in which environmental issues have been repeatedly expressed only as problems has taken attention off the positive attributes of environmental assets as producers of welfare and revenue.'

Further, complementing the analysis of Assey, climate change has now become a major issue.

The loss of habitats and biodiversity is occurring at an alarming rate, especially considering that natural resources sustain the livelihoods of the majority of the population in the country. Expanding agriculture, the clearing of forests for charcoal and firewood, climate change and desertification are the primary causes of biodiversity loss. This has a clear impact on the tourist sector, which is based largely on the country's ecosystems and wildlife (both terrestrial and marine), and which contributes more than 12% to GDP.

In order to halt and reduce the intensity of biodiversity loss, permanent and long-term solutions must be found, in the form of the development and implementation of appropriate policy guidelines, institutional capacity-building and deployment of adequate resources.

Deforestation: Forests and their products are natural resources that also sustain the livelihood of a large section of the country's population. It is estimated that the annual loss of forest area is approximately 1%, equivalent to 400,000 ha of forest cover per annum for mainland Tanzania, most of which is illegally harvested (URT, 2014*a*).

The majority of Tanzanians still depend on wood for their energy needs, causing deforestation and environmental degradation and, as a consequence, deforestation leading to biodiversity loss and land degradation due to erosion.

Overgrazing: Overstocking is assumed to be the main cause of degradation of farmland and erosion due to overgrazing; thus, it is frequently recommended to reduce stock numbers to fixed stocking rates as a primary management intervention. Changing livestock numbers without changing management practices has a minimal impact. When vegetation disappears, the ground becomes exposed to soil erosion, which greatly reduces its ability to grow new plants. Eroded soil also runs into rivers and ponds where it causes siltation.

Pollution management: The major towns and cities in Tanzania are experiencing air and water pollution as a result of discharging untreated solid and liquid wastes, a major environmental and health hazard for those who live in underprivileged areas. Tanzanian urban centres are experiencing an increase in unplanned settlements which is intensifying the challenge of access to environmental sanitation and hygiene services among urban dwellers.

Water supply and water pollution management: Efforts to enable citizens to access clean and safe water have been undertaken by the government. In rural areas, the proportion of people with access to clean and safe water increased from 6% in 1961 to 57.8% in 2011, whereas in urban areas it increased from 25% to 86% during the same period.

The rapid increase in population and demand for water has resulted in water stress in many parts of the country. Some of the main challenges are:

- Inadequate initiatives in the development of water harvesting facilities and the promotion of alternative sources of energy, both of which need an enabling environment in terms of funding;
- Environmental problems such as water pollution and wetlands degradation;
- Inadequate capacity of the private sector and local government authorities to implement irrigation projects; and

Photo 6.3. Increasing human water demands coupled with climate change impact on biodiversity. The population of elephants in the Ruaha river bed (National Park) is the biggest in East Africa though very much reduced in the last decades due to droughts and poaching.
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- Conflict among farmers and livestock keepers over water resources.

6.4. Policies addressing sustainability problems

The commitment of the Government of the United Republic of Tanzania to addressing sustainability problems is demonstrated by various initiatives.

The first is the adoption of the National Environmental Policy (URT, 1997) and the Environmental Management Act Cap 191 of 2004, with similar counterpart policies for Zanzibar (National Environmental Policy (NEP) (URT, 1997) and the Environmental Management for Sustainable Development Act of Zanzibar of 1996). These norms have been able to mainstream environmental consideration into sectoral legislation, policies and strategies. The sectors highlighted in the NEP with their respective environmental policy objectives include: agriculture; livestock; water and sanitation; health; transport; energy; mining; human settlement; industry and tourism; wildlife; forests; and fisheries.

At the same time, it is possible to identify number of institutional advances which are strengthening a sustainability approach towards development, among them:

- The establishment of various coordination institutions, such as the Division of Environment (Vice President's Office for both union and Zanzibar governments); the National Environment Management Council (NEMC); the Tanzania Commission for Science and Technology (COSTECH); the Rural Energy Agency (REA); and the Energy and Water Utility Regulatory Authority (EWURA).
- The empowerment of local government authorities through decentralization by devolution, which has demonstrated some improvements. Decentralization is a form of governance that promotes popular participation in decision making. In theory, it entails the transferring of powers and resources to the lowest levels of government. In Tanzania, improvements are expressed in some areas, particularly in capacity-building of working staff and through increases in revenue collections. However, the empowerment to enable local people to decide what they wanted to happen to them remains a challenge (Ringo and Mollel, 2014).
- An observed increase in participation of different actors, including the donor community, through the Joint Donor-Government Forum for Review of Development Strategies.

Tanzania has also implemented local and international agendas towards sustainable development, such as the Convention on Biological Diversity (CBD), the United Nations Convention to Combat Desertification (UNCCD) and the United Nations Framework Convention on Climate Change (UNFCCC), to combat loss of biodiversity, desertification and climate change respectively. Through the application of these international agreements, various achievements can be identified within the country:

- Establishment and implementation of the National Adaptation Programme of Action (NAPA); the National Action Plan to Combat Desertification (NAP); and the National Biodiversity Strategy and Action Plan (NBSAP).
- Environmental issues have been mainstreamed into the National Strategy for Growth and Reduction of Poverty (NSGRP), as well as sector and local government plans and budgets.
- Environmental issues have been incorporated in curricula for schools at various levels and higher education institutions.
- The launch of the Kilimo Kwanza Programme, subsidy agricultural inputs and the promotion of strategic grain reserves at community level.
- Various environmental programmes and projects have been implemented, for example: the Lake Victoria Environmental Management Programme (LVEMP); the Lake Tanganyika Environmental Management Project; the Lower Kihansi Environmental Management Project (LKEMP); the Eastern Arc Mountains Conservation Project; Marine and Coastal Environmental Management Project (MACEMP); the Kilimanjaro Sustainable Land Management Project (KSLM); the Mtoni Land Fill CDM Project; the Africa Adaptation Project (AAP); and forestry programmes under the Department of Forestry in Zanzibar.
- The establishment of the Parliamentary Standing Committee on Lands, Natural Resources and Environment, tree planting campaigns and the establishment of Presidential Awards on Sustainable Environmental Management (tree planting and mining) (URT, 2010*c*).

It is also noted that several of the targets defined in the 17 Sustainable Development Goals, such as in Goal 3 on good health and well-being, Goal 6 on clean water and sanitation, Goal 7 on affordable and clean energy and Goal 11 on sustainable cities and communities, are already enshrined in national strategies, including the Constitution, Vision 2025, NSGRP-MKUKUTA I and II, ZSGRP/MKUZA and the new Five-Year Development Plan FYDP II (URT, 2016*c*).

In a sustainable society, it is important to recognize the contribution that indigenous knowledge can make to economic and social developments. The indigenous knowledge system will be described further in this study.

6.5. Science, technology and innovation policy and governance

6.5.1. Historic policy background[3]

The importance given to science and technology policies in Tanzania dates back to the early 1960s. In 1963, Tanganyika participated actively in the UN Conference on the Application of Science and Technology (S&T) for the benefit of less-developed areas, and in 1968 the Tanzania National Scientific Research Council was formed. With the government's recognition of the importance of S&T capabilities, the first national S&T policy was adopted in 1985, later reviewed and reformulated in 1996 by the Ministry of Science, Technology and Higher Education. To coordinate and implement policy, COSTECH was established in 1986 by Act of Parliament 7 as a successor to the National Scientific Research Council.

The policy of 1996 was based on the recognition of several limiting factors to the implementation of the 1985 policy. Among these was the poor structuring of research and development institutions, in particular their lack of vision towards streamlining their researchers' activities, and linking them directly to current socio-economic issues. Also affecting the application of the 1985 policy were poor funding and the lack of a strategy to diffuse the use of technology and to encourage and support the emergence of indigenous technologies. Key considerations for the adoption of the new policy were the changes that had occurred in the economic process and the limitations of the previous policy in its inability to incorporate S&T in the context of the economic reform programmes, characterized by the objective of political and economic self-reliance.

The main objectives of the 1996 S&T policy were to: 1) regulate the flow of technologies and reduce excessive dependence on imported technologies; 2) guide the development of national capabilities in S&T and define priority sectors and areas for R&D with the potential to accelerate development and competitiveness; and 3) establish an effective institutional framework and linkages 'so that the various science and technology institutions and the productive sector work in a system that is focused on achieving developmental goals without undue duplication and competition'. As a result of the implementation of the 1996 policy, several other policies and legal frameworks were put in place and new institutions, including private universities, emerged.

In spite of the efforts made to implement the policy, it was considered that it fell far short of its objectives in its application. S&T could neither impact the productive sectors, nor result in commercial ventures. The central coordinating role sought for COSTECH was difficult to achieve as R&D was, and still is, under each individual line ministry. One particular shortfall of the policy was the conception and subsequent practice of S&T that seemed to be an end in itself, without the important complement of innovation.

The subsequent key milestone in S&T policy in Tanzania was the publication of the Science and Technology Sub-Master Plan (2003–2018) in 2002. The overall objective of the plan was to make operational the existing S&T policy by formulating clear issues and priorities, setting targets and timeframes, identifying resource requirements and establishing a system for monitoring and review. It was an S&T development plan expected to foster both the individual and collective development needs of Tanzanian society.

In 2008, with the creation of the Ministry of Communications, Science and Technology, a draft national science, technology and innovation policy was prepared. This was the first formal document to introduce innovation as an element for future policy definition in the country and to call for the establishment of a national innovation system, as well as establishing indigenous knowledge systems and using new and emerging technologies in the areas of information communication technology (ICT), biotechnology, new materials, nanotechnology and nuclear science.

In May 2010, the Ministry of Communications, Science and Technology (MCST), adopted a new Master Plan (2010–2020), and within it a science, technology and innovation policy. This policy is geared towards providing a framework through which the linkage, coordination and harmonization of existing and new mechanisms will support other policies and initiatives to achieve the national vision of a middle-income country by the year 2025. It is expected that through the implementation of this policy, Tanzania will be able to address the challenges of technological innovations and globalization to avoid the marginalization of the country in the global scene, relegating it to a mere supplier of raw materials.

In broad terms, this policy emphasizes that research undertaken in Tanzania should be directed towards generating knowledge

3 This subsection is summarized from Aguirre-Bastos and Diyamett (2016).

and building skills deemed to be of lasting benefit to the country, and further emphasizes the innovation and commercialization of research results which are key in bringing about economic growth, while at the same time solving societal problems.

6.5.2. The national innovation system

Figure 6.1 provides an overview of the national innovation system. As can be seen, it is composed of a wide range of public institutions, linked to their parent ministries and also a large number of public and private universities.

Governance

The R&D policy of 2010 recognizes four levels for the governance and management of R&D. The first level constitutes a high-level mechanism for policy (planning level) and national strategic positioning. The second level is constituted by the government ministry responsible for R&D governance (promotion level) – MCST. This is the instrumental level whereby the Ministry, in collaboration with other sectoral ministries, formulates policies, facilitates implementation of R&D programmes, regulates the sector, and monitors and evaluates performance. At the third level are the R&D central coordinating and regulatory bodies. Performers of R&D activities constitute the fourth level. These include public and private firms, organizations, institutions and communities (performance level).

COSTECH, under the MCST, acts as the principal advisory organ to the government on all matters pertaining to scientific research, technological development and coordination of research activities in the country, and innovation. COSTECH has a three-tier organizational structure, consisting of the Commission, R&D Advisory Committees and the Secretariat.

The Commission and R&D Advisory Committees are composed of members from both public and private universities, government departments and major national R&D institutions. This positions COSTECH as a unique body for local R&D, regional and international linkages necessary for the development of STI in the country.

The act of parliament that created COSTECH also charges it with the task of administering the National Fund for the Advancement of Science and Technology (NFAST). The fund is basically intended to support research with special emphasis on national priority areas, supporting the development and transfer of appropriate technologies, capacity-building in R&D and S&T activities in terms of human resource and research facilities.

The preparation of the National Research Agenda (NRA) is one of COSTECH's mandates. Recently, COSTECH produced the NRA and ZRA (Zanzibar Research Agenda) for 2015–2020, which aim to strengthen the national science, technology and innovation ecosystem towards realizing the Tanzania Development Vision (TDV) 2025. NRA/ZRA has been prepared through participatory and consultative processes, which involved various stakeholders from government, the private sector, and academia and community representatives. The processes also involved consultation on key national documents such as Vision 2025, Zanzibar Vision 2020, secretarial policies and strategies relevant to STI. In addition, development of the NRA takes into account contemporary social and economic challenges, including sustainability problems such as climate change, inclusive economic growth, urbanization and management of natural resources

The governance of the national innovation system includes a local government component brought about by a process of decentralization. The local government authority (LGA) is responsible for developing and implementing various projects. It has a major role in identifying areas which require further research and in the overall process of priority setting and implementation of research projects. Thus, the LGA is responsible for the preparation and enforcement of by-laws to guide research and development at the district level. Furthermore, the LGA sets aside funds for R&D to address local challenges, including promoting new technologies to end users. At the same time, the ward and village levels are responsible for the identification of innovative ideas and participating in priority setting.

R&D institutions

In Tanzania, most research is conducted by public research institutions, public higher education institutions and a handful of private research institutions. Some of the research institutions have state-of-the-art laboratories and world-class researchers and technicians. The public research institutions in the country include 17 agricultural research institutions and stations (one in Zanzibar); 6 in animal sciences and animal diseases; 9 in human health, nutrition and medical sciences; 6 in natural resources; and 7 in industry.

With the exception of the agriculture and livestock research institutions, most public research institutions are administratively organized under an umbrella body that enjoys a level of autonomy from the parent ministries. Such bodies include the Tanzania Wildlife Research Institute (TAWIRI); the National Institute for Medical Research (NIMR); the Tanzania Fisheries Research Institute (TAFIRI); and the Tanzania Forestry Research Institute (TAFORI).

Tanzania national innovation system

PERFORMANCE LEVEL

Universities

Government Institutions of Higher Education
- University of Dar-es-Salaam (UDSM)
- Sokoine University of Agriculture (SUA)
- Ardhi University (ARU)
- Mzumbe University(MU)
- Moshi Co-operative University (MoCU)
- Muhimbili University of Health & Allied Sciences (MUHAS)
- Nelson Mandela African Institution of Science and Technology (NM-AIST)
- University of Dodoma (UDOM)
- Mbeya University of Science and Technology (MUST)
- Dar es Salaam Institute of Technology (DIT)
- Institute of Traditional Medicine (ITM)
- Institute of Rural Development Planning (IRDP)
- Open University of Tanzania (OUT)

Private Institutions of Higher Education
- The Hurbert kairuki Memorial University
- Tumaini University Makumira
- St. Augustine University of Tanzania
- St John's University of Tanzania
- St.Joseph University In Tanzania
- University of Bagamoyo
- Catholic University of Health and Allied Sciences
- Zanzibar University
- State University of Zanzibar(SUZA)
- Institute of Marine Sciences (IMS)

Public Research Institutions

Ministry of Health, community Development, Gender, Elderly and Children
- Ifakara Health Institute (IHI)
- National Institute for Medical Research (NIMR)
- Tanzania Food and Nutrition Centre (TFNC)
- Kilimanjaro Clinical Research Institute (KCRI)

Ministry of Natural Resources and Tourism
- Tanzania Forest Research Institute(TAFORI)
- Tanzania Wildlife Research Institute (TAWIRI)

Ministry of Industry, Trade and Investment
- Tanzania Industrial Research and Development Organization (TIRDO)
- Small Industries Development Organization (SIDO)
- Centre for Agricultural Mechanization and Rural Technology (CAMARTEC)
- Tanzania Engineering and Manufacturing Design Organization (TEMDO)
- Tanzania Automotive Technology Centre (TATC)
- National Housing and Building Research Agency (NHBRA)

Ministry of Livestock and Fisheries
- Tanzania Livestock Research Institute (TALIRI)
- Tanzania Fisheries Research Institute (TAFIRI)

Ministry of Agriculture
- Tanzania Agricultural Research Institute (TARI)
- Tanzania Veterinary Laboratory Agency (TVLA)
- Tanzanian Coffee Research Institute (TaCRI)
- Tea Research Institute of Tanzania
- Tobacco Research Institute of Tanzania
- Tropical Pesticides Research Institute (TPRI)
- ARI Kizimbani, Zanzibar

Independent organisations
- Economic and Social Research Foundation (ESRF)
- International Institute of Tropical Agriculture (IITA)
- Tanzania Chamber of Commerce Industry and Agriculture (TCCIA)
- Research on Poverty Alleviation (REPOA)
- Economic and Social Research Foundation (ESRF)

SCIENTIFIC AND TECHNOLOGICAL SERVICES LEVEL

Tanzania Bureau of Standards

Tanzania National Bureau of Statistics

Export Priority Zone Authority (EPZA)

National museums of Tanzania

Figure 6.1. Organizational chart showing Tanzania's research and innovation system.

Source: Authors' production based on GO→SPIN methodology (UNESCO, 2015).

A number of private organizations have started to engage in research, largely in the social sciences. These institutions include the Economic and Social Research Foundation (ESRF); Research for Poverty Alleviation (REPOA); the Tanzania Gender Networking Programme (TGNP); the Society for Women and Aids in Africa-Tanzania (SWAAT) and private universities. In addition, there are a small number of private research institutions that are involved in scientific research. These include: the Ifakara Health Institute (IHI); the Tea Research Institute of Tanzania (TRIT); the Tanzania Coffee Research Institute (TaCRI); the Tanzania Technology Development Organization (TaTEDO); and the Science, Technology and Innovation Policy Research Organization (STIPRO).

6.5.3. The indigenous knowledge system

Policies and strategies adopted throughout the years in Tanzania have called for indigenous knowledge to make an important contribution to development. More particularly, it is considered as a key tool for sustainability. In spite of its evident importance, indigenous knowledge currently has no official protection mechanism, except in the case of folklore, where protection is assured by the Copyright and Neighbouring Rights Act, Cap 218 (URT, 1999). At the regional level, Tanzania is not a signatory to the Swakopmund Protocol on the Protection of Traditional Knowledge and Expressions of Folklore.

In spite of the above limitations, there are a number of initiatives for incorporating indigenous knowledge into mainstream research and educational activities, as well as applications, as shown in **Table 6.2**.

Table 6.2. Initiatives for the development of the indigenous knowledge system

	Initiatives	Purpose
	Health sector	
1	Establishment of The Institute of Traditional Medicine (ITM), under the Muhimbili University College of Health Sciences, Act of Parliament No. 9 of 1991, Section 10 (1) (c)	The Institute is responsible for research into traditional healing systems in Tanzania, in order to identify useful practices which can be adopted and also to identify materia medica which can be modernized and developed into drugs to improve human health
2	A national office was established as the Traditional Medicine Section of the Department of Curative Services at the Ministry for Health and Social Welfare in 1998	The office oversees issues relating to policy and the development of traditional medicine, and is responsible for the health policy review
3	Health Policy of 1990 (reviewed in 2003/2007/2015) Healthy Policy Act No. 23 of 2002 on Traditional and Alternative Medicines, introduced coordinator of TM at regional and district level	• The Ministry of Health recognizes the role and contribution of traditional and alternative healthcare in the health status of people • The Ministry of Health, in collaboration with ITM, organizes a one-week annual training event for TM practitioners
4	The Traditional and Alternative Medicine Control Act No. 23 of 2002 for URT and Zanzibar Traditional and Alternative Medicine Policy of 2008	• Makes provision for the promotion, control and regulation of traditional and alternative medicines • Encourages the improvement of traditional medicine use and control
5	Establishment of Alternative Health Practice Council	• Registration of TM practitioners (approx. 15,000 to date) • Registration of TM service centres (200)
6	S&T Policy 1986	• Scientific use of TM in healthcare • Use of indigenous materials to produce low-cost drugs and equipment • Research on the use and effectiveness of medicinal plants • Transfer of TM from informal to formal sector of healthcare delivery
7	STI Policy 2016 in preparation	• R&D institutions to exploit indigenous knowledge and technology. In ensuring the sustainable growth of STI in the country, there are a number of cross-cutting issues that need to be addressed, including good governance, economic performance and management • Enhancing national scientific and technological culture is essential for a vibrant and effective STI performance. Eventually, all activities related to STI in the county to ensure environmental sustainability
	Educational sector	
8	In 2008, Local and Indigenous Knowledge Systems (LINKs) Trust, with support from COSTECH, developed and published a resource book on local and indigenous knowledge and practices (Mgumia, 2009).	A pilot resource to integrate local and indigenous knowledge in order to improve secondary school learning

Source: by authors from various documents.

6.5.4. The university system

The number of universities in Tanzania has increased – currently, the total number (including affiliates) stands at 71, of which 19 are public and the remaining 52 private, as shown in **Table 6.3**. Despite the fact that there are fewer public universities than private, they have a higher number of students.

Most of the newly-established universities and colleges undertake very few research activities in the fields of science and technology, partly due to the heavy capital investment required. All major universities in Tanzania are strong in research activities aimed at sustainable development.

Table 6.3. Tanzanian university institutions

Type of institution	Public	Private	Total
Fully-fledged universities	12	21	33
University colleges	2	14	16
University campuses, centres and institutes	5	17	22
Total	**19**	**52**	**71**

Source: http://www.tcu.go.tz/images/documents/RegisteredUniversity.pdf (Accessed 22 February 2016).

The more recently established Nelson Mandela African Institute of Science and Technology (NM-AIST), based in Arusha, is intended to be a fully-fledged research university where all academicians (faculty, students, research chairs and research fellows) engage in rigorous, responsible and responsive research and innovation that focuses on the problems and needs of society and industry. In order to achieve this, research is organized in multi- and transdisciplinary centres and groupings, involving local and external collaborators and partners; issues for research are drawn from society and industry, with a view to producing solutions that can be applied. Research students and postdoctoral students join research groups when joining NM-AIST, local and international collaborations are highly emphasized and currently there are over 60 of these, with other institutions worldwide. Locally, NM-AIST leverages its international networks and shares knowledge and expertise derived from the global knowledge society, translating this to address local needs and problems.

Universities in Tanzania, as in other parts of Africa, have been undergoing a post-independence transformation, characterized by strong public funding and government control. New realities and inadequate public funding are forcing universities to become more connected to the world through collaborations with outside universities, focusing on staff and student exchange, joint research, joint publications and capacity-building in newly emerging areas of study such as oil and gas.

6.5.5. Situation of the national innovation system

The national innovation system of Tanzania is fragmented, and thus has difficulty in responding to set national policy, or even to S&T objectives as defined in their respective policies. Some of the main features of the system are discussed briefly below.

The enabling environment

In the years of liberalization and privatization, there was a deliberate policy on the part of government that wrongly sought a completely 'hands-off' approach to research. This meant pushing the public R&D institutions to market their competencies and technologies and cutting resources for S&T, without providing the necessary incentives for innovation to entrepreneurs, and without making any investment in public goods. Neither were any appropriate regulations set down to enable a climate to stimulate innovation. This saw a number of public R&D institutions suffer in terms of research and innovation outputs. Fortunately, this is now changing with the Fifth Phase Government in place.

In spite of recent advances, a supportive environment for private sector involvement in research is still lacking, with inadequate mechanisms for technology transfer and the commercialization of research results.

Financial resources

The present expenditure on R&D is below the stated permanent target level of 1% of GNP (Global Innovation Index, 2018), Today, a large part of the funds used for research in Tanzania still come from donors (42%), while the input from government to both university research and public research institutions is around 58%. The private sector conducts very little R&D and hardly finances R&D in research institutions.

Research funds are insufficient to support activities that can completely address the country's priority areas, and where funds have been available, they have not been directed to research projects for a sufficient amount of time to enable their findings to be used in addressing societal problems. With inadequate funding, universities in particular are yet to be engaged in carefully selecting priority areas and defining areas of strength

where they can make a difference. Universities still work across too many areas of research, with too few human resources, low infrastructure and low funding, so that research cannot complete the innovation process.

Advanced human resources

The human resource base is small. The number of researchers (full-time equivalent) per million inhabitants is 18.5, according to the Global Innovation Index (2018) – one of the most relevant weaknesses of the national innovation system. This indicator puts Tanzania in 100th place out of 142 countries in the innovation index. In addition, the majority of researchers and Ph.D.-holders are working at universities (around 90%) where their teaching loads are high, especially where undergraduate teaching is involved, and this has a major impact on time dedicated to R&D. Further, Ph.D.-holders at universities have very few funds available to allow them to concentrate on research. The other 10% of researchers are employed in government.

A study on innovation systems in selected African countries (NEPAD, 2011), including Uganda and Tanzania, has shown that there is only a small number of qualified technical personnel to carry out innovation activities in industries. Low levels of interaction, knowledge generation, utilization and diffusion, as well as low STI human capacity, coupled with a low knowledge economy index contribute to the weak innovation trend and hence low levels of industrialization in EAC industries (World Bank, 2006).

Photo 6.4. Women represent only 24% of full time equivalent (FTE) researchers in Tanzania.
© UNESCO/J. Chaves-Chaparro

It is also observed that this weakness in the human resource base stems from poorly developed doctoral or post-doctoral studies. COSTECH is finalizing a post-doctoral framework which will soon be implemented.

Research infrastructure

Adequate research infrastructure is another area of weakness in the research system of Tanzania. Few organizations would claim to have an adequate and well-maintained infrastructure for research. At the same time, where there is a good level of infrastructure, the absence of collaboration between institutions does not provide for its optimal use.

Linkages with other systems

The national innovation system is generally weakly linked to other systems that are key to its success. However, there are areas where the link to other system(s) is evident. For example, research systems under ministries in sectors such as agriculture and livestock, as well as wildlife and health, are very well connected to the other systems within the mandates of the parent ministries. Such research bodies include the Tanzania Wildlife Research Institute (TAWIRI), the National Institute for Medical Research (NIMR), the Tanzania Fisheries Research Institute (TAFIRI), the Tanzania Forestry Research Institute (TAFORI), and the Zanzibar Agriculture Research Institute (ZARI).

Linkages between academic research and civil society or private entities are evidenced by the many innovative cluster initiatives in Tanzania, exemplified by the Zanzibar Seaweed Cluster Initiative (ZaSCI). The academia component of the initiative has developed farming and value-addition technologies that have been adopted directly by seaweed farmers, thereby enhancing their livelihoods and those of their communities.

There are some areas where the research and innovation system seems to be well-connected to users and local and indigenous knowledge holders. The Institute of Traditional Medicine (ITM) of the Muhimbili University of Heath and Allied Sciences has been closely collaborating with local traditional healers in developing traditional medicine.

A key issue in every meeting discussing research in Tanzania is that of the weak link to industrial systems, in particular on the part of universities. On the other hand, as the Tanzanian industrial sector is still very weak, it has not yet understood how best to use universities and research organizations to add value to its processes and products.

Transfer of technology

Tanzania has established policy instruments, governing bodies and interventions to ensure that new knowledge, either locally generated or imported, is transferred and used to produce sustainable solutions and empower society, including: the

National Fund for Advancement of Science and Technology (NFAST) managed by COSTECH; the Tanzania Investment Bank (TIC); the Business Registrations and Licensing Agency (BRELA); and the Plant Breeders' Rights Registration Office. Some of the initiatives are specific to the transfer of technology, for example the seed subsector of the Agricultural Seed Agency (ASA), established under the Executive Agencies (Act No. 30 of 1997). The agency aims to ensure that high quality agricultural seeds are available to farmers at an affordable price. One of the functions of the agency is to increase private sector participation in the development of the seed industry through the establishment of public-private partnerships or joint ventures in seed production and distribution.

Commercialization of research results

The economic characteristics of generated knowledge have a considerable influence on the type of actors involved in technology transfer, and hence the extent of the transfer of that knowledge, its use and its sustainability (Mgumia et al., 2015*a*). For example, many agricultural companies fail to capture and 'sell' the benefits of their innovations, such as seeds of open-pollinated varieties, which mean that private seed companies prefer to commercialize hybrid varieties. Thus, actors in the research domain of this kind of technology are linked to entrepreneurs and the market through innovation intermediary roles. These roles, which include testing and demonstration of new technologies, articulating the demand for new technologies by potential users, negotiation for business partnerships and financial support, are embedded within R&D institutions and NGOs but operate mainly in a project set-up, thus they are not sustainable (Mgumia et al., 2015*b*).

One recent innovative programme on seed law and regulation, led by the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) Centre Ltd. (SCL), developed legal and regulatory systems to enable the development, access and availability of high-quality agricultural inputs to Tanzania's small-scale farmers. The framework includes the legal and regulatory framework for seeds, putting the correct laws, regulations and institutions in place.

Knowledge and technology outputs

The research output, as measured by the number of publications in peer reviewed journals, is shown in **Table 6.4**. Compared with other African countries, Tanzania is ranked 9th in terms of number of publications. The corresponding outputs by sector and the respective H-Index are shown in **Figure 6.2**. The analysis also shows that the leading institutions in cited publications are the University of Dar es Salaam (1,294 publications), Sokoine University of Agriculture (1,002 publications), Muhimbili University of Health and Allied Sciences (987 publications), the National Institute of Medical Research (599 publications) and Ifakara Health Institute (579 publications).

Table 6.4. Research outputs

Rank[1]	Country	Documents	Citable documents	Citations	Self-citations	Citations/ document	H-Index
1	United States	9 360 233	8 456 050	202 750 565	94 596 521	21.66	1783
2	China	4 076 414	4 017 123	24 175 067	132 97 607	5.93	563
3	United Kingdom	2 624 530	2 272 675	50 790 508	11 763 338	19.35	1099
4	Germany	2 365 108	2 207 765	40 951 616	10 294 248	17.31	961
5	Japan	2 212 636	2 133 326	30 436 114	8 352 578	13.76	797
6	France	1 684 479	1 582 197	28 329 815	6 194 966	16.82	878
67	Kenya	24 458	22 347	379 560	57 594	15.52	179
78	Ethiopia	13 363	12 626	118 656	24 840	8.88	101
84	Tanzania	11 964	11 140	170 144	25 866	14.22	122
87	Uganda	11 528	10 599	171 367	26 995	14.87	128
137	Rwanda	1 759	1 554	15 356	1 456	8.73	54

[1]Out of 239 countries and territories.
Source: Scimago Lab, (2007–2016). Data Source: Scopus®, www.scimagojr.com.

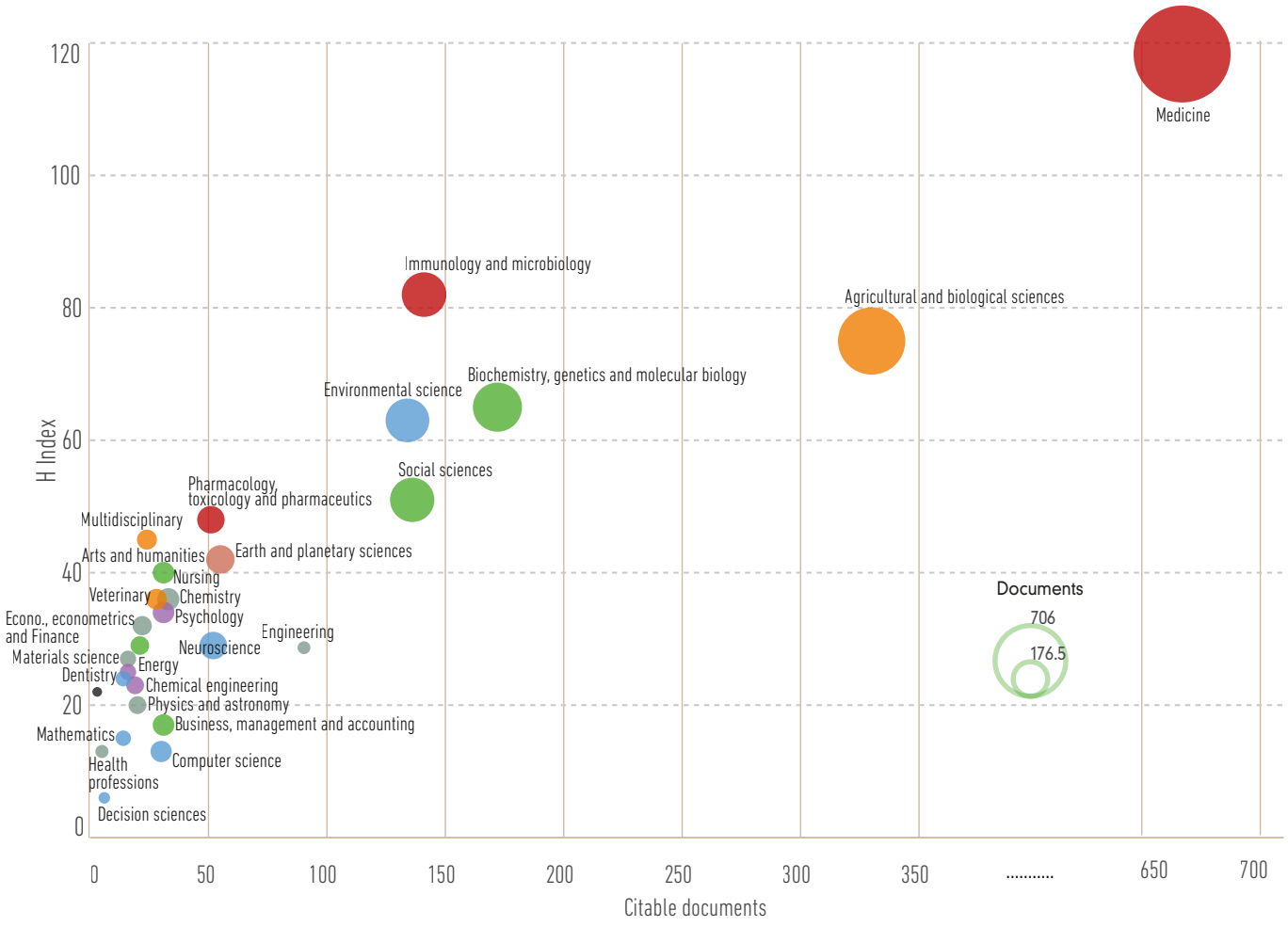

Figure 6.2. Number of Tanzanian publications in various fields with corresponding H-Index

The technology outputs as registered by the GII (2018) put Tanzania in 123th place out of 126 countries in granted patents by origin, and 102nd in Patent Convention Treaty applications (1 in 2002, 2 in 2015); and 2 patents in 2011 and 1 in 2015 in the Madrid System (see WIPO, 2018.)

The main fields of technology for which patents were filed were 25% in medical technology; 20% in pharmaceuticals; and 15% in management methods. The utility model applications show only one in 2013 and none for industrial design registration.

It should be noted here that multidisciplinary and transdisciplinary research – even within the same institution – is minimal, although this is increasing. Institutional collaborations are also minimal, and in a few cases, there is collaboration between civil society and non-academic areas and research units. A number of them are in the area of traditional medicine research and in agriculture.

Knowledge generation for policy-making

Research results should not only serve to increase knowledge or to develop technology and innovation processes, they should also inform policy-making and strategy.

Evidence-based policy is a much-discussed issue in both developed and developing countries, and there is a wealth of literature around it. In the specific case of Tanzania, Diyamett et al. (2016) carried out research with an emphasis on agriculture and health, which shows that, in general, a large part of knowledge generated is not put to use. One observation of this study is that there exists a notable difference between the health and agricultural sectors, where health is very much dominated by policy-oriented research, while this is much less so for agriculture. In any case, however, this study shows the need to strengthen policy-oriented research, as the country requires knowledge-based decision-making processes and, moreover, because scientifically informed decisions are key to improving governance.

6.6. Building capacity to face sustainability challenges

6.6.1. National innovation system

The national innovation system is contributing to resolving sustainability problems in a number of areas. Some of these include:

a) 'Towards enhanced sustainability of strategic research and innovation systems for inclusive development in Tanzania' programme

The programme is divided into sub-programmes that work towards enhanced sustainability. The University of Dar es Salaam (UDSM) has partnered with the Swedish Program for ICT in Developing Regions (SPIDER), which is a centre at the Royal Technical University (KTH), to implement a project on **'Strengthening research management at the University of Dar es Salaam'.** UDSM, in collaboration with SPIDER and DSV, employs digital platforms to enhance the participation of academic staff members and students in:

- Strengthening efficiency on research management;
- Increasing research capacity and quality of outputs;
- Increasing the dissemination of research results to end-users; and
- Strengthening research networks and collaboration with key stakeholders.

b) Sustainable charcoal project

The Tanzania Forest Conservation Group (TFCG), in partnership with the Tanzanian Community Forest Conservation Network (MJUMITA) and the Tanzania Traditional Energy Development Organization (TaTEDO), is implementing the 'Transforming Tanzania's charcoal sector' project. The project aims to establish a commercially viable value chain for legal, sustainably produced charcoal. The project is financed by the Swiss Agency of Development and Cooperation (SDC). The project began in March 2012 and a second four-year phase began in November 2015.

c) Sustainable Agriculture Tanzania (SAT)

SAT is a non-profit organization that addresses social and environmental problems caused by environmentally-destructive and unsustainable farming practices, which lead to food insecurity, poverty and malnutrition resulting from environmental degradation through loss of top soil, water supplies and forests.

d) Sustainable management of mineral resources

This is a World Bank-funded project which aims to strengthen the government's capacity to manage the mineral sector in order to improve the socio-economic impacts of large- and small-scale mining for Tanzania, and to enhance private local and foreign investment.

e) Promoting sustainable management of the Mara Wetlands – Tanzania

The goal of this project is to conserve and protect the Mara Wetlands Biodiversity Sensitive Area in Tanzania by: 1) Strengthening the governance of local, district, national and regional institutions for sustainable transboundary wetland management; and 2) Increasing the awareness of Mara wetland values and promoting sustainable alternative livelihood approaches for the benefit of nature and people.

f) Market infrastructure, value addition and rural finance (MIVARF) support programme

Financed under the 11th European Development Fund, the objective of this programme is to enhance the income and food security of the target group sustainably through increased access to financial services and markets. Its focus is to improve access for poor rural people to a wider range of financial services for productivity-enhancing technologies, services and assets, sustainable agricultural input and output markets, and opportunities for rural enterprise.

g) Traditional knowledge in the management of coastal and marine resources in Tanzania: with emphasis on fisheries resources.[4]

The monitoring of fisheries resources and contemporary rules for coastal and marine resource management in Tanzania has been challenged because of their inadequacy. A study was undertaken to investigate the role of traditional knowledge in the management of coastal and marine resources in rural and urban coastal communities of Tanzania. The study found that fish catch assessments can be inferred from fishers' knowledge. Local fishers reveal that at the present time, common fish catches have been significantly overexploited in urban areas compared to rural areas, based on their size and quantity. Some common fish catches, such as Caranx Spp., are most vulnerable to fishing pressures, while others such as Chanoschanos were consistently reported to be missing from the catch. Moreover, traditional management practices in the study areas are dominated by taboos and customs, but compliance with many of these practices was found to decrease with time, especially in urban areas, due to rapid socio-economic changes. This study suggests actions to protect traditional knowledge in

4 Ph.D. dissertation, University of Dar es Salaam (Shalli, 2011)

order to ensure sustainable conservation of coastal and marine resources in Tanzania.

h) Management of urban wastewater in Zanzibar

The World Bank Tanzania, Zanzibar Urban Services Project (ZUSP) was established to treat urban wastewater while working with the responsible ministries. This project is among those set up following the establishment of the Local Government Act No. 7 of 2014 Sec. 26 (1) (d), which empowers/requires local councils to keep respective areas clean by proper management of waste. A number of projects on solid waste management have been/are being implemented, an example of which can be found in a study by Abdulrasoul and Bakari (2016), among others.

6.6.2. Success stories for co-designed, collaborative, interdisciplinary sustainability research, technology or innovation

Chololo Ecovillage

The Chololo Ecovillage project is part of the Global Climate Change Alliance (GCCA), an initiative of the European Union, with a focus on helping the most vulnerable developing countries to more effectively address the challenges associated with climate change.

Although developing countries have contributed the least to greenhouse gas emission, they are often the most affected by climate change and have limited resources to address the challenges. Tanzania has experienced a mean annual temperature

Photo 6.5. Subsurface sand dam at Chololo
© Karoli Nicholas Njau

Photo 6.6. Women in Semi arid areas (Dodoma) fetching firewood from up hills
© Karoli Nicholas Njau

increase of 1 °C since 1960. Annual rainfall has decreased at an average of 3.3% per decade. Six major droughts over the past 30 years caused severe damage to agriculture production, which provides one-third of its GDP, income and employment to more than 80% of the population. Extreme events, such as drought, floods, tropical storms and cyclones, are expected to become more frequent, intense and unpredictable.

Chololo was identified as the most vulnerable village to climate change impacts by a multidisciplinary team that visited three rural villages in Dodoma. The team used for its work a methodology based on a vulnerability matrix of participatory Climate Vulnerability and Capacity Analysis (CVCA), developed by Care International (CARE, 2009). The key issues identified were drought, deforestation, floods, strong winds, human diseases, livestock diseases, crop pests and inadequate ground water recharge. As a result, the project on 'Empowering vulnerable rural communities to adapt and mitigate the impacts of climate change in central Tanzania' was implemented in Chololo village from September 2011 to May 2014.

The project worked with the community to identify, introduce, test, evaluate and take up a holistic range of integrated innovations, spanning agriculture, livestock, water, energy and forestry. In agriculture, the project introduced a package of ecological technologies to make the most of the limited rainfall, improve soil fertility, reduce farmers' workload, and improve the quality of local seeds. Such technologies included the use of improved early-maturing, high-yielding seeds; varieties of sorghum and pearl millet; ox-drawn tillage implements such as the 'Magoye ripper'; soil water conservation measures such as contour ridges; farmyard manure; optimum plant population; intercropping and crop rotation. Chololo Ecovillage reports

successes in the various interventions introduced (Ephrahim and Fadhili, 2014).

The agricultural innovations have been very successful in increasing yields. Pearl millet increased from 450 kg to 1,500 kg/ha and sorghum from 500 kg to 900 kg/ha, meaning more household food security and more income from cash crop sales. The project has increased the genetic potential of livestock in the village through the introduction of improved goat breeds (Blended Goat Bucks) and chickens (Rhode Island Red and White Sussex Cocks) (Njau et al., 2013). This has improved the productivity of the crossbred animals, producing more meat and eggs more quickly and hence more income. The goat keepers report increased sales of offspring, with buyers paying around TZS 50,000, double the price of local breeds, reflecting their increased weight as breeding stock. The improved goats are producing twins, whereas the local breeds only produced single offspring. The crossbred goats grow much faster, so they can be sold at the age of 12 months instead of 2 years, creating more profit for the owner.

Water shortage was a major problem in the village. The Chololo Ecovillage project tackled this issue through the introduction of solar power water pumps and rainwater harvesting systems at a primary school, capturing 60,000 l of water for pupils and teachers, and the construction of a subsurface dam that captures thousands of tons of water in the sandy river bed, providing water for domestic use and livestock through the dry season. Mgohachi testifies that 'Since the installation of solar water pumps, water is available every day. The price of water has gone down from TZS 50 in the past to TZS 25 per bucket. When we were using the diesel engine pump, there were frequent breakdowns and we were using a lot of money for repairs, and during the repair water was not available'.

Photo 6.7. Low cost Energy Saving Stove in Chololo Eco-village
© Karoli Nicholas Njau

The Chololo Ecovillage project has increased access to natural resources through tree planting and agroforestry, and has increased the use of energy-saving stoves. The project has trained 133 community members and village leaders on afforestation, nursery management and tree planting. It has also created tree nurseries at primary schools and community institutions and planted 36,650 tree seedlings. On average, each household planted 14 trees of which 65% survived. To reduce the use of firewood, the project introduced energy-saving stoves to 240 Chololo homes. The project trained 12 women to construct energy-saving stoves, carried out community sensitization and provided a subsidy of TZS 5,000 to cover labour costs. Households were asked to collect the raw materials needed: clay soil, grasses and water. The stoves are a local adaptation of the rocket stove design developed by the German Development Agency (GIZ) (Kees and Feldmann, 2011). The assessment carried out by the project revealed that using energy-saving stoves cuts down fuel wood use by 57%, reduces household CO2 emission by 1.4 tons per year, saves TZS 85,000 or up to 17 days per year collecting firewood, and reduces the risks associated with firewood collection.

The project was funded by the European Union and implemented by a partnership of six organizations, led by The Institute of Rural Development Planning (IRDP). The partners are Dodoma Municipal Council, the Dodoma Environmental Network, the Hombolo Agricultural Institute, Majina Maendeleo Dodo ma and the Tanzania Organic Agriculture Movement. The project was so successful that the funder awarded IRDP another fund to roll out the best practices to other three villages in Dodoma Municipal Council and Chamwino District Council, build capacity in local governments, and set up a knowledge management system from March 2015 to September 2019.

Sustainable management of waste

Researchers from the University of Dar es Salaam and the Nelson Mandela African Institute of Science and Technology, in collaboration with researchers from Makerere University in Uganda and Addis Ababa University in Ethiopia, have developed a method for the management of industrial waste through a Sida-funded 'Bio-Innovate' project. The result was an innovative process, summarized in **Figure 6.3**, whereby agro waste undergoes a series of treatments, resulting in a biogas, organic fertilizer and clean water for reuse. The biogas is used within the production facility and the organic fertilizer can be processed, packaged and either sold or distributed to small-scale farmers around the processing factory. The treated water, which has some residual nutrients, is used for crop irrigation. This approach was successfully implemented at Banana

Investment Limited (BIL) (Paschal et al., 2017) in Arusha, a winery company producing an alcoholic beverage made from bananas. The investment of US$150,000 for the innovation was paid by BIL and Sida contributed US$404,084 through the Bio-Innovate Project. The Sida component also addressed the research component of the innovation.

The same process has been adopted by Mwanza City abattoir and a similar treatment system has been installed for treating abattoir wastewater, thus preventing the pollution of Lake Victoria. The Mwanza project has been financed by the World Bank through the Lake Victoria Environmental Management Project II (LVEMP II).

The innovation has been awarded a second phase by the 'BioInnovate Africa' programme to develop a regional enterprise to commercialize the innovation, which is incubated at NM-AIST.

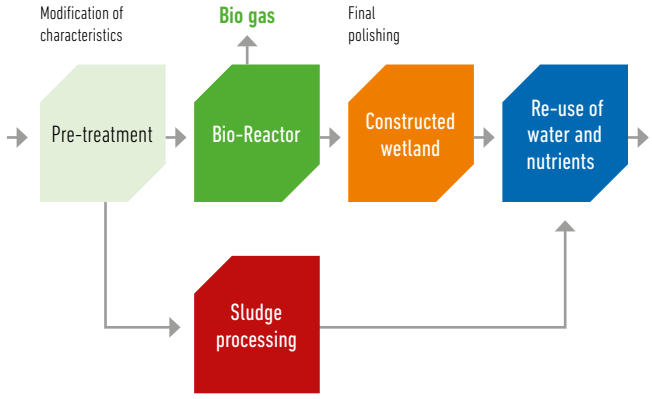

Figure 6.3. General layout of scheme for treatment of industrial wastewater, realizing recovery of energy and organic fertilizer.
Source: Personal notes of Prof. K.N. Njau.

Photo 6.8. Water treatment plant designed by a university-industry partnership for the Banana Investment Limited company in Arusha (Tanzania)
© Karoli Nicholas Njau

6.7. Conclusions

The innovation system's approach certainly has the potential to address the challenges posed by sustainability problems, and has become embedded in government discourse since the early 2000s. In addition, the new Research and Development Policy 2 (2010) has many features that could be used to address the current challenges facing the innovation system in Tanzania. The sector's R&D policies, however, are defined by sector ministries, and each sector administers their R&D organizations, therefore the ministry responsible for STI needs to be properly empowered to fulfil its objectives. Furthermore, the National Environmental Policy of 1997 has been able to mainstream environmental consideration into sectoral legislation, policies and strategies. In spite of these advances, there is still an inadequate supportive environment for private sector involvement in research and inadequate mechanisms for technology transfer and the commercialization of research results.

Resource gaps, both human and financial, are the main challenges that constrain the ability of the Tanzanian government and in particular the national innovation systems, to address sustainability problems in a comprehensive way. Public finance for STI initiatives is unstable; researchers' participation in policy advice, either directly or through their scientific findings, is insufficient; and the short-term profit orientation of the private sector is also a limitation for their involvement in STI. Other contributory factors to sustainability problems include limited infrastructure and equipment in research and higher education institutions; poor assessment of STI impact indicators and data availability; and a lack of implementation instruments in existing S&T frameworks.

Addressing sustainability challenges also requires inter- and transdisciplinary research approaches, which do not occur automatically by bringing together several disciplines in research projects. To successfully form a consistent research team from different disciplines, their communication methods need to be considered, along with institutional structures, standard operational procedures and diverse perceptions/views. This can be achieved by researchers acquiring new skills such as flexibility, willingness to learn from other disciplines, being open-minded to ideas coming from other disciplines and experiences, and learning to bridge the gaps between theory and practice. The introduction of interdisciplinary courses in university curricula can be one way of building trust between different disciplines. COSTECH is in the process of establishing a Tanzania framework which would guide postdoctoral activities in Tanzania – this is an opportunity to increase human resource capital in R&D activities. These postdoctoral students would be posted to support research and innovation activities in research and academic institutions.

Photo 6.9. The blue economy has great potential in Tanzania, with a strong R&D system enabling improved traditional practices and social innovation. Fishing ships used for tourism in Dar es Salam.
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Knowledge generation is critical to innovation; policies to encourage innovation therefore need to be integrated with policies to support the generation of knowledge. Generally, knowledge is considered to be generated from research and higher education institutions, hence funding is also channelled in that direction. In promoting the innovation of 'sustainable solutions', support through the traditional institutions may no longer be sufficient, because successful innovation depends on a more interactive and participative form of knowledge production.

Engaging the right partners in innovation processes is another obstacle to the cohesion of research teams. It is also important to consider that different stakeholders in the interdisciplinary research teams or projects are motivated by different reward systems depending on their institutional structures, which need to be included in the research strategy.

To ensure that new knowledge, both locally-generated and imported, is transferred and used to produce sustainable solutions, Tanzania has established specific policy instruments and governing bodies. The functions of these policy instruments and governing bodies include increasing private sector participation in innovation processes through the establishment of a conducive and attractive environment for public-private partnerships or joint ventures. In addition, the nature of knowledge production is changing and becoming more evenly distributed. Research institutions are not the only source of key knowledge for successful innovation – knowledge and experience from industry and civil society also have a major role to play. Against this broader context of the need for greater interactivity among distributed sources of knowledge, policy support for environmental innovation should consider a number of features such as risk, uncertainty and new emerging technologies, and should also encourage diverse technical options and long-term commitment.

Photo 6.10. Co-production and exchange of knowledge are essential for SDG 2, and are key to the country's sustainability.

This country profile is from the Africa SDG Index and Dashboards Report 2018 (p.136-137). It is reprinted with permission from SDGC/A and SDSN. For more information , please visit https://africasdgindex.org

TANZANIA
East Africa

OVERALL PERFORMANCE

Index score

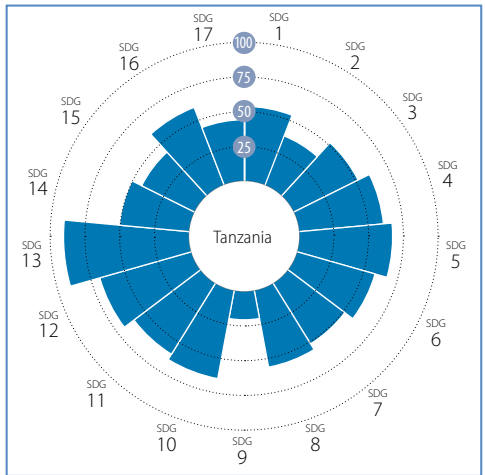
54.7

Regional average score

50.1

Africa Index Rank

19 (OF 51)



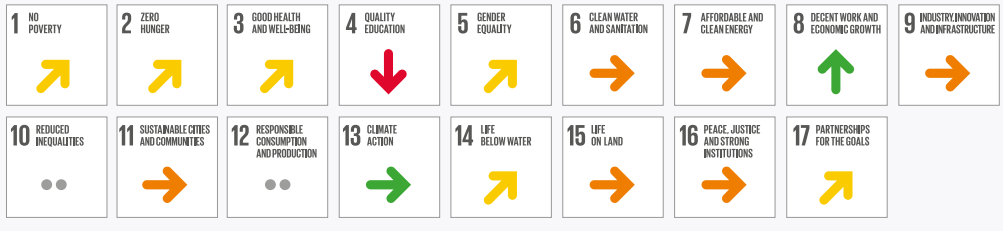
AVERAGE PERFORMANCE BY SDG

COMPARISON WITH OTHER AFRICAN INDICES

	RANK	SCORE
Africa Gender Equality Index (2015)	12 (of 52)	64.2 / 100
Africa Infrastructure Development Index (2016)	43 (of 54)	12.54 / 100
Africa Regional Integration Index (2016)	36 (of 52)	0.43 / 1
Ibrahim Index on African Governance (2017)	17 (of 54)	57.5 / 100

CURRENT ASSESSMENT – SDG DASHBOARD

SDG TRENDS



Notes: The full title of Goal 2 "Zero Hunger" is "End hunger, achieve food security and improved nutrition and promote sustainable agriculture".
The full title of each SDG is available here: https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals

Figure 6.4. Tanzania Country Profile 2018

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

TANZANIA
Performance by Indicator

SDG1 – End Poverty	Value	Rating	Trend
Poverty headcount ratio at $1.90/day (% population)	37.7	●	↗
Projected poverty headcount ratio at $1.90/day in 2030 (% population)	14.8	●	••
Proportion of population living below the national poverty line	28.2	●	••
Population covered by Social Protection (%)	9.0	●	••

SDG2 – Zero Hunger	Value	Rating	Trend
Prevalence of undernourishment (% population)	32.3	●	••
Prevalence of stunting (low height-for-age) in children under 5 years of age (%)	34.8	●	↗
Prevalence of wasting in children under 5 years of age (%)	6.6	●	↑
Prevalence of obesity, BMI ≥ 30 (% adult population)	8.4	●	→
Cereal yield (t/ha)	1.5	●	↓
Fertilizer consumption (kg per hectare of arable land)	8.8	●	→

SDG3 – Good Health and Well-Being	Value	Rating	Trend
Maternal mortality rate (per 100,000 live births)	398.0	●	↑
Births attended by skilled health personnel (%)	63.7	●	••
Neonatal mortality rate (per 1,000 live births)	21.7	●	↗
Mortality rate, under-5 (per 1,000 live births)	56.7	●	↑
HIV prevalence (per 1,000)	1.6	●	↑
People living with HIV receiving antiretroviral therapy (%)	62.0	●	••
Incidence of tuberculosis (per 100,000 people)	287.0	●	↑
Proportion of children under 5 with fever who are treated with appropriate anti-malarial drugs (%)	53.7	●	••
Malaria mortality rate	34.1	●	→
Coverage of Preventive Chemotherapy for Neglected Tropical Diseases (%)	63.9	●	••
Age-standardised death rate due to cardiovascular disease, cancer, diabetes, and chronic respiratory disease in populations age 30–70 years (per 100,000 population)	17.9	●	↓
Traffic deaths rate (per 100,000 people)	33.4	●	↓
Adolescent fertility rate (births per 1,000 women ages 15-19)	116.6	●	→
Universal Health Coverage Tracer Index (0-100)	49.1	●	→
Age-standardised death rate attributable to household air pollution and ambient air pollution (per 100,000 population)	94.1	●	••
Percentage of surviving infants who received 2 WHO-recommended vaccines (%)	90.0	●	→
Healthy Life Expectancy at birth (years)	61.8	●	↑
Subjective Wellbeing (average ladder score, 0-10)	3.3	●	↗

SDG4 – Quality Education	Value	Rating	Trend
Net primary enrolment rate (%)	79.0	●	↓
Mean years of schooling (years)	5.8	●	→
Literacy rate of 15-24 year olds, both sexes (%)	85.8	●	••

SDG5 – Gender Equality	Value	Rating	Trend
Proportion of women aged 20-24 years who were married or in a union before age 18	30.5	●	••
Proportion of girls and women aged 15-49 years who have undergone female genital mutilation/cutting, by age	10.0	●	••
Seats held by women in national parliaments (%)	36.4	●	↗
Women in ministerial positions (%)	20.0	●	••
Estimated demand for contraception that is unmet (% women married or in union, ages 15-49)	34.8	●	↑
Ratio of female to male mean years of schooling of population age 25 and above (%)	87.1	●	••
Ratio of female to male labour force participation rate	90.9	●	→

SDG6 – Clean Water and Sanitation	Value	Rating	Trend
Population using at least basic drinking water services (%)	50.1	●	→
Population using at least basic sanitation services (%)	23.5	●	→
Freshwater withdrawal as % total renewable water resources	7.5	●	••
Imported groundwater depletion (m^3/year/capita)	0.7	●	••

SDG7 – Affordable and Clean Energy	Value	Rating	Trend
Access to electricity (% population)	15.5	●	→
Access to clean fuels & technology for cooking (% population)	2.0	●	→
Renewable energy share in the total final energy consumption	86.7	●	→
Consumer affordability of electricity	100.0	●	••

SDG8 – Decent Work and Economic Growth	Value	Rating	Trend
5-year average GDP growth per capita (%)	3.4	●	••
Employment-to-population ratio	76.4	●	→
Slavery score (0-100)	50.0	●	••
Adults (15 years and older) with an account at a bank or other financial institution or with a mobile-money-service provider (%)	46.8	●	↑
Starting a Business score	48.4	●	↑

SDG9 – Industry, Innovation and Infrastructure	Value	Rating	Trend
Infrastructure score (0-100)	36.1	●	••
Logistics performance index: Quality of trade and transport-related infrastructure (1=low to 5=high)	2.8	●	••
Research and development expenditure (% GDP)	0.5	●	••
Number of scientific and technical journal articles (per 1,000)	0.0	●	••
Mobile broadband subscriptions (per 100 inhabitants)	8.9	●	→
Proportion of the population using the internet (%)	13.0	●	→

SDG10 – Reduced Inequalities	Value	Rating	Trend
Gini Coefficient adjusted for top income (1-100)	41.6	●	••

SDG11 – Sustainable Cities and Communities	Value	Rating	Trend
Proportion of urban population living in slums	50.7	●	••
Improved water source, piped (% urban population with access)	58.9	●	↓
Satisfaction with public transport (%)	56.0	●	↑
Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5) in urban areas (µg/m^3)	23.3	●	↓

SDG12 – Responsible Consumption and Production	Value	Rating	Trend
Municipal Solid Waste (kg/year/capita)	0.3	●	••
E-waste generated (kg/capita)	0.5	●	••
Natural Resource Value Realization Score	59.4	●	••
Production-based SO_2 emissions (kg/capita)	0.5	●	••
Anthropogenic wastewater that receives treatment (%)	1.4	●	••
Net imported SO_2 emissions (kg/capita)	0.4	●	••

SDG13 – Climate Action	Value	Rating	Trend
Climate Change Vulnerability Monitor (best 0-1 worst)	0.1	●	••
Energy-related CO_2 emissions per capita (tCO_2/capita)	0.2	●	→
Imported CO_2 emissions, technology-adjusted (tCO_2/capita)	0.2	●	••
CO_2 emissions embodied in fossil fuel exports (kg/capita)	1.3	●	••

SDG14 – Life Below Water	Value	Rating	Trend
Percentage of inadequately managed plastic waste	83.5	●	••
Ocean Health Index Goal - Clean Waters (0-100)	54.6	●	↑
Ocean Health Index Goal - Biodiversity (0-100)	80.9	●	→
Ocean Health Index Goal - Fisheries (0-100)	66.7	●	↑
Mean area that is protected in marine sites important to biodiversity (%)	43.7	●	••
Percentage of Fish Stocks overexploited or collapsed by EEZ (%)	16.4	●	••
Fish caught by trawling (%)	2.8	●	→

SDG15 – Life on Land	Value	Rating	Trend
Mean area that is protected in terrestrial sites important to biodiversity (%)	53.6	●	→
Percentage change in forest area (2010-2015)	-2.1	●	••
Red List Index of species survival (0-1)	0.7	●	↓
Imported biodiversity threats (threats/capita)	0.2	●	••

SDG16 – Peace, Justice and Strong Institutions	Value	Rating	Trend
Homicides (per 100,000 people)	7.0	●	••
Conflict-related deaths per 100,000	0.0	●	→
Proportion of the population who feel safe walking alone at night in the city or area where they live (%)	65.0	●	↗
Children 5–14 years old involved in child labour (%)	28.8	●	••
Property Rights (0-100)	55.2	●	↓
Access to justice (0-100)	65.7	●	↓
Corruption Perception Index (0-100)	36	●	↓
Public Sector Accountability & Transparency (0-100)	66.1	●	→
Birth registrations with civil authority, children under 5 years of age (%)	26.4	●	••

SDG17 – Partnerships for the Goals	Value	Rating	Trend
Tax revenue (% GDP)	16.2	●	→
Government Health and Education spending (% GDP)	9.1	●	••
Level of customs duties on imports	54.8	●	••
Visa Requirement score	64.0	●	••
Governmental Statistical Capacity	71.1	●	↑

Figure 6.5. Tanzania performance by indicator.

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

References

Abdulrasoul, A. A. and Bakari S. S. 2016. Challenges and problems of solid waste management in three main markets in Zanzibar. *Advances in Recycling & Waste Management*, Vol. 1, p. 109.

Aguirre-Bastos, C. and Diyamett, B. 2016. The emergence of the national innovation system's approach in Tanzania. B. Goransson, C. Brundenius and C. Aguirre-Bastos (eds), *Closing the Loop in Developing Countries, the Innovation Systems in Bolivia, Mozambique, Tanzania and Vietnam*. Cheltenham (UK), Edward Elgar Publishing.

Assey, P., Bass, S., Cheche, B., Howlett, D., Jambiya, G., Kikula, I., Likwelile, S., Manyama, A., Mugurusi, E., Muheto, R. and Rutasitara, L. 2007. *Environment at the Heart of Tanzania's Development: Lessons from Tanzania's National Strategy for Growth and Reduction of Poverty (MKUKUTA)*. Natural Resource Issues Series No. 6. London, International Institute for Environment and Development.

CARE. 2009. *Climate Vulnerability and Capacity Analysis Handbook*. www.careclimatechange.org

CIA. 2018. *CIA World Factbook 2018*. https://www.cia.gov/library/publications/the-world-factbook/fields/2012.html

Country Watch. 2018. *Country Review: Tanzania*. www.countrywatch.com

Deloitte and Touche. 2017. *Tanzania Economic Outlook 2017: Joining the Dots, Dar es Salaam*. Available at: https://www2.deloitte.com/content/dam/Deloitte/tz/Documents/tax/tz-budget-economic-outook-2017.pdf

Diyamett, B., Thomas, T., Daniel, L., Liberio, J. and Aguirre-Bastos, C. 2016. National innovation system in Tanzania: Making research and innovation matter. B. Goransson, C. Brundenius and C. Aguirre-Bastos (eds), *Closing the Loop in Developing Countries, the Innovation Systems in Bolivia, Mozambique, Tanzania and Vietnam*. Cheltenham (UK), Edward Elgar Publishing, pp.184–229.

Ephrahim, K. V. and Fadhili, B. 2014. Climate change adaptation in semi-arid Dodoma: An experience from Eco-Village. *Journal of Challenges,*Vol. 2, pp. 30–42.

Global Innovation Index. 2018. *Global Innovation Index 2018: Energizing the Wold with Innovation*. Ithaca, Fontainebleau, Geneva, SC Johnson College of Business, Cornel University; INSEAD Business School; World Intellectual Property Organization.

International Bank for Reconstruction and Development/World Bank. 2014. *World Development Indicators*. Also available at: https://open knowledge. worldbank.org/ bit stream/ handle/10986/.../9781464801631.pdf?

Kees, M. and Feldmann, L. 2011. The role of donor organisations in promoting energy efficient cook stoves. *Energy Policy,* Vol. 39, pp. 7595–99.

Mgumia, A. H. 2009. Local and indigenous knowledge and practices. A resource to integrate local and indigenous knowledge to improved secondary school learning (unpublished).

Mgumia, A. H., Mattee, A. Z. and Kundi, B. A. T. 2015*a*. Contribution of innovation intermediaries in agricultural innovation: The case of agricultural R&D in Tanzania. *African Journal of Science, Technology, Innovation and Development* Vol. 7, No. 2.

Mgumia, A. H., Mattee, A. Z. Kundi, B. A. T. 2015*b*. The application of the agricultural innovation system approach in technology development in Tanzania: Researchers' perceptions and practices. *African Journal of Science, Technology, Innovation and Development*, Vol. 7, No. 3.

NEPAD. 2011. *African Innovation Outlook 2010*. Pretoria, ASTI Programme.

Ngowi, H. P. 2009. *Economic Development and Change in Tanzania since Independence: The Political Leadership Factor*. Also available at: www.academicjournals.org/article/article 1379789169_Ngowi.pdf

Njau, F., Lwelamira, J. and Hyandye, C. 2013. Ruminant livestock production and quality of pastures in the communal grazing land of semi-arid central Tanzania. *Livestock Research for Rural Development,* Vol. 25.

Paschal, C., Gastory, L., Katima, J. and Njau, K. N. 2017. Application of up-flow anaerobic sludge blanket reactor integrated with constructed wetland for treatment of banana winery effluent. *Water Practice & Technology*, pp. 667–74.

Planning and Coordinating Agency (NPCA). 2014. *African Innovation Outlook 2014*. Pretoria, NCPA.

REN21. 2016. *EAC Renewable Energy and Energy Efficiency Status Report*. Paris, REN21 Secretariat.

Ringo, C. J and Mollel, H. A. 2014. Making decentralization promote empowerment of the local people: Tanzanian experience. *International Journal of Business and Social Science,* Vol. 5, No. 12.

Shalli, M. S. 2011. Traditional knowledge in the management of coastal and marine resources in Tanzania, with emphasis on fisheries resources. Ph.D. dissertation (Aquatic science), University of Dar es Salaam.

Simmonds, S. 2014. Curriculum-making in South Africa: Promoting gender equality and empowering women. *Gender and Education.* Vol. 26, No. 6, pp. 636–52.

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network. Available at http://africasdgindex.org

UNESCO. 2015. *Mapping Research and Innovation in the Republic of Rwanda*. GO→SPIN Country Profiles in Science, Technology and Innovation Policy, Vol. 4. Paris, UNESCO.

United Nations, Department of Economic and Social Affairs, Population Division. 2017. *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables*. Working Paper No. ESA/P/WP/248.

URT. 1997. *National Environmental Policy*. Dar es Salaam, Vice-President's Office, United Republic of Tanzania.

URT. 1999. Copyright and Neighbouring Rights Act, Cap 218, Enacted by Parliament on June 2, 1999, No. 7 of 1999

URT. 2000. *United National Development Vision: Vision 2025*. Dar es Salaam, United Republic of Tanzania.

URT. 2010*a*. *National Strategy for Growth and Reduction of Poverty (NSGRP II)*. Dar es Salaam, Ministry of Finance and Economic Affairs.

URT. 2010*b*. *Water Quality Management and Pollution Control Strategy in Tanzania*. Dar es Salaam, Ministry of Water.

URT. 2010*c*. *National Strategy for Growth and Reduction of Poverty*. Dar es Salaam, United Republic of Tanzania.

URT. 2014*a*. *State of the Environment Report II*. Dar es Salaam, Vice President's Office Division of Environment, United Republic of Tanzania.

URT. 2014*b*. *Fifth National Report on the Implementation of the Convention on Biological Biodiversity*. Available on: https://www.cbd.int/doc/world/tz/tz-nr-05-en.pdf

URT. 2015. *2014 Tanzania in Figures*. Dar es Salaam, National Bureau of Statistics.

URT. 2016*a*. *2015 Tanzania in Figures*. Dar es Salaam, National Bureau of Statistics.

URT. 2016*b*. *Tanzania Service Provision Assessment Survey 2014–2015*. Dar es Salaam, National Bureau of Statistics. Available from: www.nbs.go.tz

URT. 2016*c*. *National Five Year Development Plan 2016/17–2020/21*. Dar es Salaam, Ministry of Finance and Planning.

USAID. 2018. *USAID Fact Sheet*. https://www.usaid.gov/sites/default/files/documents/1860/Gender_and_Youth_Fact_Sheet_2018_ENGLISH_FINAL.pdf

Walby, S. 1990. *Theorising Patriarchy.* Oxford, Basil Blackwell Ltd.

Weatherston, J. 2017. Does gender inequality still exist within education in Tanzania and to what extent? *Social Science Blog*, University of Sunderland, October.

WHO. 2014. *Noncommunicable Diseases (NCD) Country Profiles*. http://www.who.int/nmh/countries/tza_en.pdf

WIPO. 2018. *Statistical Country Profiles, United Republic of Tanzania*. Geneva, World Intellectual Property Organization. (Accessed on 20 March 2018.)

World Bank. 2006. *Fostering Innovation, Productivity, and Technological Change: Tanzania in the Knowledge Economy*. www.worldbank.org/curated/en/268441468313494613/Fostering-innovation-productivity-and-technological-change-Tanzania-in-the-knowledge-economy.

World Bank. 2016*a*. Tanzania economic update: the road less travelled – unleashing public private partnerships in Tanzania*. Tanzania Economic Update*, Vol. 8. Washington, DC, World Bank Group. Available at: http:// documents.worldbank. org/curated/en/302151467992051044/Tanzania-economic-update-the-road-less-traveled-unleashing-public-private-partnerships-in-Tanzania.

World Bank. 2016*b*. *Service Delivery Indicators Programme*. Washington DC, World Bank, African Economic Research Consortium and African Development Bank.

World Bank. 2018. *Tanzania Economic Overview*. World Bank. https://www.worldbank.org/en/country/tanzania/overview

7

Harnessing science and technology knowledge for sustainability in Uganda

7. Harnessing science and technology knowledge for sustainability in Uganda

Maxwell Otim Onapa,
Steven Sebbale,
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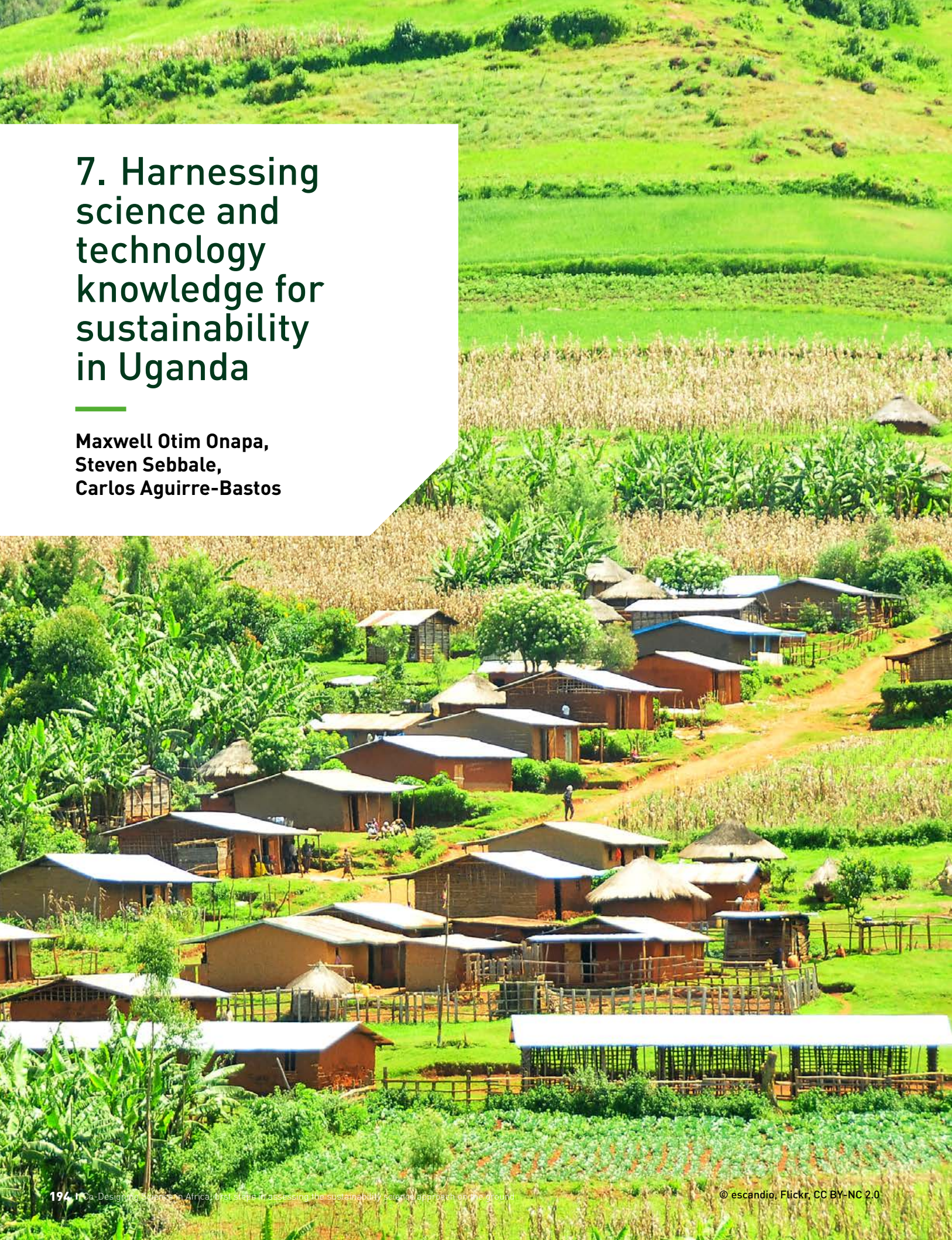

7.1. Introduction

Uganda is a landlocked country, located in East Africa astride the equator, and bordered on the west by Congo, on the north by the Sudan, on the east by Kenya, and on the south by Tanzania and Rwanda. Lake Victoria forms part of the southern border. The country is divided into three main areas – swampy lowlands, a fertile plateau with wooded hills and a semi-arid region. Uganda has a total area of 241,551 km^2 (200,523 km^2 land and 41,028 km^2 water cover). The 2014 census estimated Uganda's population at 34.6 million, with an estimated growth rate of 3.03% (UNBS, 2017).

Uganda is a country endowed with substantial natural resources, including fertile soils, regular rainfall, deposits of copper, iron, gold and other minerals. Its economy is fundamentally agro-based, agriculture being the most important economic sector, employing nearly two-thirds of the workforce with coffee being the biggest export revenue earner. Despite its importance, this sector is heavily constrained by a reliance on rudimentary technologies, including hand-held hoes, low use of fertilizer, and lack of irrigation, among others. The industrial sector is small and heavily dependent on imported inputs such as oil and equipment. The sector is constrained by the high cost of energy, poor infrastructure, low levels of private investment and the depreciation of the Ugandan shilling.

To face its social and economic challenges, the Uganda government approved in 2007 the National Vision Statement, 'A transformed Ugandan society from a peasant to a modern and prosperous country within 30 years' and the National Planning Authority, in consultation with other government institutions and different stakeholders, developed a Uganda Vision 2040 to make this vision statement operational (GoU, 2007).

To implement the vision, five five-year National Development Plans have been envisioned. At present, the second plan (NDPII) is being executed. The goal of this plan is to propel the country towards middle-income status by 2020 through strengthening the country's competitiveness for sustained and inclusive growth, with particular emphasis on the creation of employment. The plan clearly recognizes that achieving Uganda's transformational goal will depend on the country's capacity to strengthen key social and economic sectors, such as infrastructure; land use management; urbanization; human resources; and peace, security and defence. Science, technology and innovation (STI) is given a high priority in the plan as one of the key sectors expected to contribute to the attainment of the country's aspirations.

Underpinned by the above context, Section 7.2 reviews the economic and social conditions, highlighting both the existing strengths and weaknesses. Sections 7.3 and 7.4 review respectively the main sustainability challenges and the efforts being made to overcome them; particular attention is given to sustainability problems related to the impact of refugees and also of water-related issues, both of key importance to the country today.

Section 7.5 reviews the situation of the national innovation system, the policies adopted for its governance, and the plans to implement them. This section highlights the efforts made towards strengthening the national innovation system, which

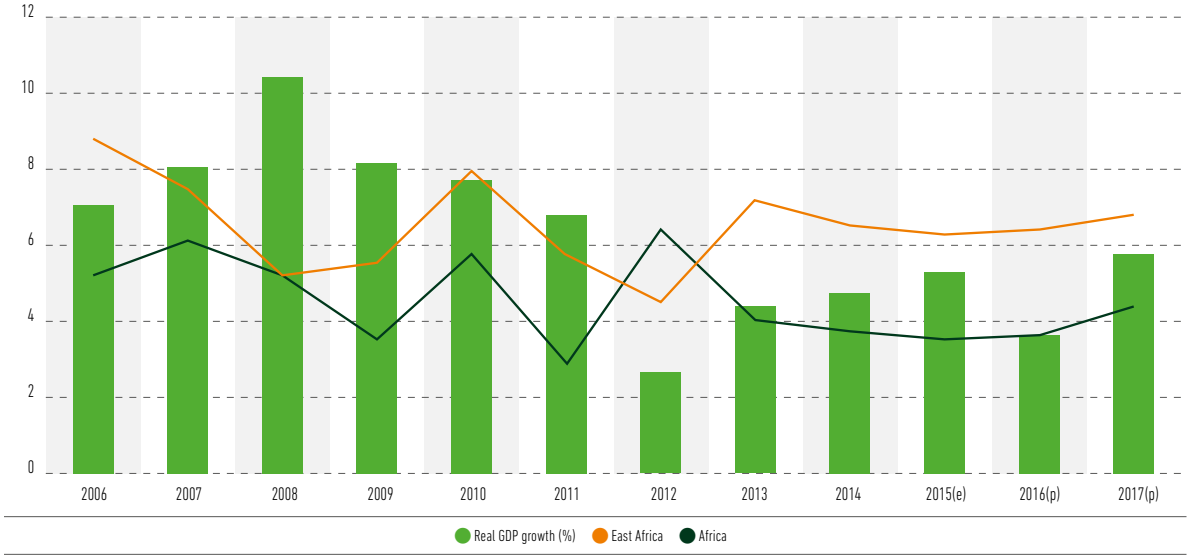

Figure 7.1. Real GDP growth.
Source: AfDB, 2018.

has turned Uganda into a successful innovation economy, when compared to countries at similar stages of development (Ecuru and Kawooya, 2015). Section 7.6 provides a résumé of three case studies highlighting the contribution of research and innovation to sustainable development processes.

7.2. The socio-economic situation

7.2.1. The economic context

Uganda has experienced sustained economic growth in the past decade, as can be seen in **Figure 7.1**. This growth, however, has been lower than the East African average in the years after 2012. The economy is projected to grow 5.9% in 2018, up from 4.8% in 2017. The main sectors contributing to GDP are services (54.5%), agriculture (24.5%) and industry (21%) (CIA, 2018; World Bank, 2018). The majority of the population is engaged in agriculture, which employs 71.9% of the workforce, while services and industry employ 23.7% and 4.4%, respectively.

The agricultural sector includes fisheries, animal husbandry, dairy and crop subsectors. Agriculture is considered a leading sector for future economic growth in the present development plan. However, for the sector to continue leading the economy, several challenges need to be addressed, including regulatory measures, commercialization and opportunities for value-addition and trade, public spending on agricultural research and extension other than via input subsidies (World Bank, 2018).

The industrial sector includes manufacturing, construction and electricity supply subsectors. In their review of Uganda's industrial policy, Ggoobi et al. (2017) point out that efforts to achieve Vision 2040 are being hampered mainly because Uganda has a weak national industrial policy. So far, it is indicated, only about 30% of the proposed objectives have been executed – mostly in policy formulation – for the sugar, textiles, iron ore and cereals subsectors. Several constraints are identified that limit the implementation of policy, which are of direct interest to this study: a skills gap in certain key areas of manufacturing, competition from low-cost producer countries and production of sub-standard products. In terms of policy, Ggoobi et al. recommend that the government urgently review both the content and realization of its industrial policy, focusing on clustering, infrastructure development, harnessing technology, encouraging innovation and raising productivity, as well as providing incentives for manufacturing.

The services sector is made up of wholesale and retail trade, telecommunications, hotels and restaurants, transport and communications, and tourism subsectors. As noted and analysed by a study by UNCTAD (2011), the National Strategy for Poverty Reduction has focused on four future growth areas: professional, insurance, accountancy and construction services. More recently, the tourism subsector has received attention, as well as financial and other related subsectors. As a whole, the service sector should be able to continue growing and contributing to GDP, as noted below, with research and innovation making important inputs to this contribution.

New investment in the energy sector, particularly oil – despite today's fluctuations in prices – is also expected to boost growth. The granting of new licences for further oil exploration in the greater Albertine region is expected to boost much-needed foreign direct investment (Silvia, 2014).

One important component of Uganda's economy is the informal sector, which constitutes about two-thirds of the country's businesses and thus contributes significantly to the country's GDP. To foster productivity in the sector, efforts have been made by several NGOs and bilateral cooperation agencies with programmes centred on improving the skills of youth and women, in order to build up business capabilities. These programmes are complemented by local initiatives and, in particular, by the 'Skilling Uganda Programme' (GoU, 2011) established by the government in 2011.

Given the government's efforts to increase and sustain higher rates of economic growth, future economic prospects in Uganda look promising. Nevertheless, development experts point out that economic growth rates of at least 7% per annum are needed if Uganda is to achieve middle-income status within the next two or three decades (Ecuru and Kawooya, 2015). Higher rates of growth will also require present policies and strategies for research, innovation and environmental management to be fully implemented and further innovative transformation policies to be designed.

Many of the social and economic achievements in Uganda, as well as many other African countries, can be attributed to foreign aid. In fact, 'since the mid-1990s, Uganda has enjoyed an influx of foreign aid amounting to 80 percent of its development expenditures and has been the beneficiary of a number of generous donor initiatives' (Branch, 2011, p. 84)

Supporters of aid to Africa, and to Uganda in particular, point out that developments in infrastructure and economic growth, including debt relief initiatives, can be associated with a range of specific programmes carried out under the UN Millennium Project, African Development Bank, World Food Programme, the

International Fund for Agriculture and Development and a score of other multilateral and bilateral cooperations.

Critics argue that, due to foreign aid, Uganda is more indebted today than ever before. It is calculated that 'approximately USD 3,100 million is owed to the multilateral creditors with World Bank, IMF, and African Development Bank being the main creditors' (Kazimbazi and Alexander, 2011, p. 29).

It should be recognized that there are many opportunities for the country to become less aid-dependent, for example through reforming public expenditure and the country's taxation system, increasing the levels of domestic investment, and achieving better deals for its agricultural products in an international market. These initiatives, however, will be successful only if the country increases its support to research and innovation processes.

7.2.2. The social context

Uganda's Human Development Index (HDI) falls within the category of low human development, despite its improvement from a 0.396 score in 2000 to a 0.493 score in 2015, growing at an average annual rate of 2.05%. The rise of the index value was mainly caused by policies addressing gender inequities. However, the index still falls below the 0.502 average for the world's least developed countries (LDCs), and the 0.518 average for sub-Saharan Africa (CIA, 2018). Some of the main social characteristics of the country are given below.

Demographics

Between 1969 and 2014, Uganda's annual population growth rate was 2.88% and it is predicted that it will reach 46.7 million (up from 34.6 million) by the year 2025 (UBS, 2014*a*). As noted by Ecuru and Kawooya (2015), although a healthy growing population is commendable, such a demographic trend, with a growing young population, places significant pressure on limited resources: 'Such a rapidly growing population requires simultaneously expanding the economy to accommodate the people's needs and adopting more sustainable practices in natural resource management. It is, therefore, absolutely critical for Uganda to turn to innovation and the creative use of resources across all sectors of the economy'. (See also Klasen and Lawson, 2007).

It is particularly important to recognize that an overwhelming majority (88%) of Ugandans still live in rural areas and are dependent on agriculture for their livelihood. Thus, population growth in these areas will most likely entrap the country in poverty and instability (Daumerie and Madsen, 2010).

Uganda has one of the youngest populations in the world, with 77% under 30 years of age. It is estimated that there are about 7.4 million youth within the age bracket of 15–24 years living in Uganda (UBS/ICF, 2017). Its total fertility rate is also among the world's highest at 5.8 children per woman. Except in urban areas, actual fertility exceeds women's desired fertility by one or two children. This is indicative of the widespread unmet need for contraception, lack of government support for family planning, and a cultural preference for large families. High numbers of births, short birth intervals, and the early age of childbearing contribute to Uganda's high maternal mortality rate. **Figure 7.2** shows the country's population pyramid.

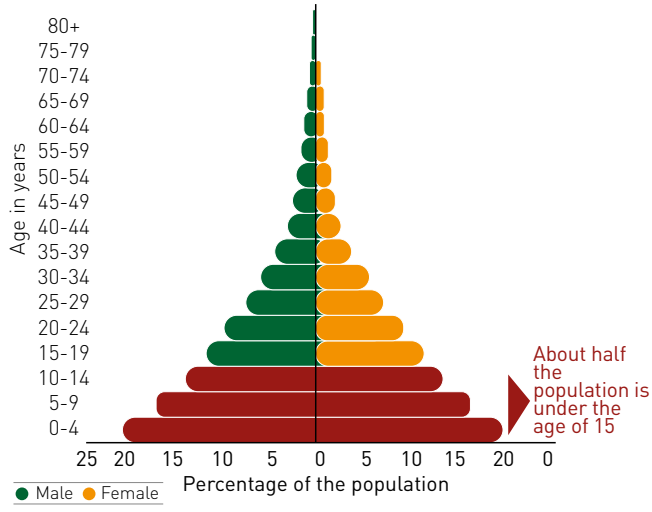

Figure 7.2. Uganda's population pyramid, 2009.
Source: Uganda Bureau of Statistics, 2017.

Africa's young population is often touted as a demographic dividend – a major advantage for the continent according to the World Economic Forum on Africa 2016, as it could generate 11–15% GDP growth between 2011 and 2030. However, without the provision of opportunities and access to good education and health services, this increasing working-age population might have negative implications, which could play into frustration, social unrest or unmanaged migration (UNFPA, 2013).

Poverty and inequality

Uganda has made impressive progress in poverty reduction. The country was one of the fastest in sub-Saharan Africa to reduce the share of its population living on US$1.90 PPP per day or less, from 53.2% in 2006 to 34.6 % in 2013 (World Bank, 2016*a*). Poverty reduction among agriculture-based households accounted for 79% of national poverty reduction from 2006 to 2013.

Despite this impressive progress, approximately 25% of the population still live in extreme poverty, most of them in rural areas (World Bank, 2016). The proportion of people living in poverty in northern and eastern regions increased from 68% to 84%, or 2.45 million to 2.5 million people in eastern Uganda and 3.45 million to 3.10 million in northern Uganda between 2006 and 2013. Poverty fell in all regions except the eastern region, where it increased between 2009/10 and 2012/13. Although the northern region has witnessed a significant reduction in poverty – from 60.7% in 2005/06 to 43.7% in 2012/13 – it still remains more than twice the national average. This situation is attributed to the long-term conflict of 1981 to1986 and more than 20 years of insurgency, as well as the ongoing inter-communal violence, land conflicts and periodic natural disasters occasioned by climate change and other factors.

In addition to the poverty rates, vulnerability rates are also high, as the majority of households who have escaped from poverty still remain at risk. Between 2005 and 2009, for every three Ugandans who were lifted out of poverty, two fell back due to high vulnerability to adverse shocks and the limited availability of safety net programmes (World Bank, 2017).

In order to achieve the development goals set in Vision 2040, Uganda must take priority action to fight poverty in a sustainable manner. The high incidence and increased concentration of poverty in the northern and eastern regions suggests a need for special policy instrument targeting of these regions. The vulnerability of households to adverse shocks implies that there is a need for appropriate strategies for building resilience and safety net programmes. There is evidence that the agricultural sector has played a critical role in poverty reduction, implying the need to intensify effective agricultural interventions throughout the country. It is considered (World Bank, 2017) that sustained poverty reduction will require a shift in the productive model, both in terms of modernizing agricultural production and increasing the share of employment and added value of non-agricultural activities.

On the one hand, besides continuing conditions of serious poverty, Uganda faces a challenge in equality for development. When discounted for inequality, the HDI for 2015 of 0.493 falls to 0.341 (UNDP, 2016). On the other, the GINI index stands at 41 in 2016, as compared to 37.8 in Tanzania; 50.4 in Rwanda; 48.5 in Kenya; and 33.2 in Ethiopia.

Gender policies

Uganda's affirmative action in education and politics has delivered some successes. Parity in primary schooling has almost been achieved and the representation of women in university education is near parity, except in science and technology courses. Following the introduction of an affirmative action policy in 1989/1990, women's enrolment at university level has substantially increased to almost 50% in some universities.

An affirmative action policy in politics has also substantially increased the number of women to more than 35% in parliament, and to a minimum of one-third in all local governments in the country (IPU, 2011; GoU, 1997). However, women still make up only 22% of senior management public service positions and 16% of middle management positions, and women continue to face discrimination, particularly in access to economic opportunities and ownership of assets.

The National Development Plan (NDP) 2010/11–2014/15 (GoU, 2010) underlines gender inequality as one of the binding constraints to Uganda's development progress. The National Gender Policy of 2007 and the National Action Plan on Women of 2008 (see UNDP, 2014) underpin the need to achieve equality between women and men and highlight specific actions for key players in gender mainstreaming and empowerment.

Some of the barriers that have been identified as hindering women's participation in public service include: absence of specific targets for women's participation, difficulty in balancing career and domestic responsibilities, recruitment, appointment, promotion and allowances – even though the public service is based on merit and gender-neutral criteria. Sexual harassment and women's unequal access to education, among other factors, are a concern for the empowerment of women.

Health

During recent years, several achievements in health have been reported in the National Resistance Movement Manifesto 2016–2021 (NRM, 2016), the most outstanding of which include:

a) Improved life-expectancy from 46.42 years in 2000 to 57.10 years in 2015;

b) Reduction in maternal mortality from 435/100,000 in 2010 to 360/100,000 live births in 2015 and reduction in infant mortality from 76/1,000 in 2010 to 44/1,000 live births in 2015;

c) Reduction in under-five mortality from 90/1,000 to 69/1,000 (2011–2014) live births;

d) Reduction of HIV prevalence to 7.3% (2011);

e) Increased and improved health units and infrastructure with consequently improved access for the population to health facilities, which stands at 75% within 5 km;

f) Improved immunization coverage for children and 11 killer diseases, including cancer of the cervix;

g) Improved staffing levels, working and educational conditions in the health sector;

h) Improved capacity to diagnose and control dangerous disease outbreaks, such as Ebola and Marburg fevers; and

i) Local capacity to manufacture critical medicines, including antiretrovirals (ARVs) and antimalarial drugs.

Food and nutrition insecurity

Achieving food and nutrition security remains a challenge for Uganda's sustainable development agenda. An estimated 10.9 million people in Uganda experienced acute food insecurity by January 2017, of which 1.6 million were in a crisis situation (IPC, 2012; IPC, 2017). In addition, about 69% of the total population in the country experienced minimal food security (IPC Phase 1) and another 26% faced stressed food insecurity (IPC Phase 2) during the January 2017 period. The January 2017 food insecurity situation, when compared with the November 2015 and July 2016 assessments, shows an increase in the percentage of the country's population that are in Phase 2 (stress level of food insecurity) and Phase 3 (crisis level), implying a deteriorating situation since then. The causes of food insecurity are: poor crop harvests due to droughts, crop and livestock diseases; low purchasing power due to low household incomes; breakdown of the culture of food storage and preservation, among others (IPC, 2017).

Malnutrition is also a major problem, as evidenced by **Figure 7.3**. In 2016, chronic malnutrition measured by restricted ('stunted') growth in children under five years only reduced from 33% in 2011 to 29%. Reduced growth is greater among children in rural areas (30%) than in urban areas (24%). About 4% are emaciated ('wasted'), down from 5% in 2011 and 11% are underweight, down from 14% in 2011 (UBS/ICF, 2017). The high levels of undernourishment compromise the well-being of mothers and children, leading to a high disease burden.

7.3. Main sustainability challenges

Environmental challenges pose critical challenges to sustainable development in Uganda. The Environmental Performance Index (EPI) (Hsu et al., 2016) provides a measure on countries' performance on high-priority environmental issues in two broad policy areas: protection of human health from environmental harm and protection of ecosystems (ecosystem vitality). Within these two policy objectives, the EPI has scored country performance in 9 issue areas comprised of 20 indicators. **Table 7.1** provides the rankings for the countries in this study, all countries having improved their scores in the last ten years. Uganda is ranked 135th globally and 3rd among the 5 study countries where Kenya ranked best, but with a global position of 123rd out of 178 countries. This section will review some of the more pressing environmental threats to the country.

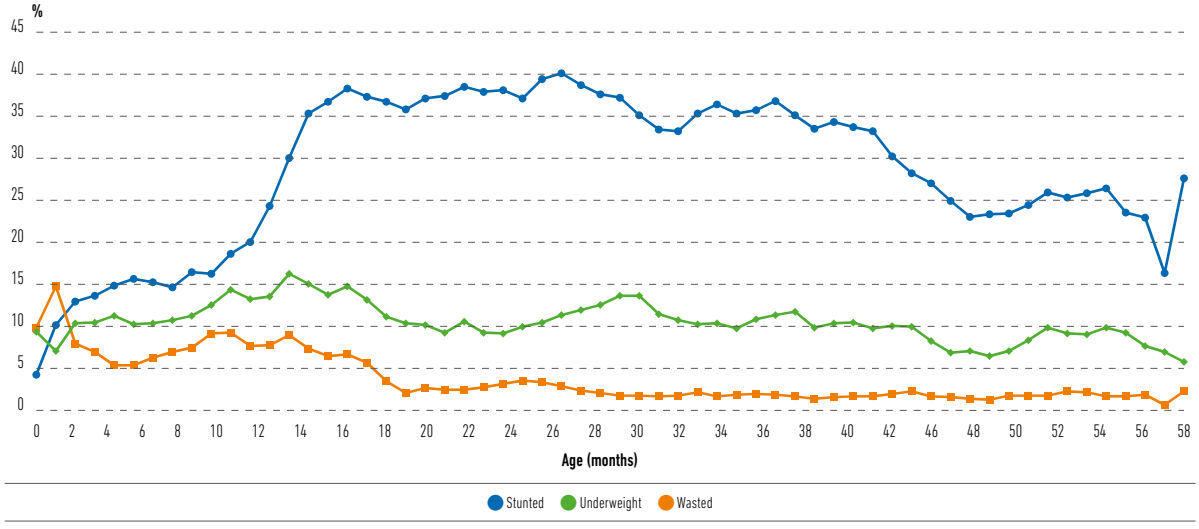

Figure 7.3. Nutritional status of children in Uganda by age.

Source: Uganda Bureau of Statistics - UBOS and ICF. 2018. Uganda Demographic and Health Survey 2016. Kampala, Uganda: UBOS and ICF. Available at http://dhsprogram.com/pubs/pdf/FR333/FR333.pdf.

Table 7.1. Ranking in the Environmental Performance Index (Score 0 to 100) (178 countries)

Rank in 2016	Country	Score
123	Kenya	62.49
132	Tanzania	58.34
135	Uganda	57.56
147	Rwanda	50.34
163	Ethiopia	45.83

Source: Hsu et al., 2016.

7.3.1. Deforestation and land degradation

Uganda is experiencing high rates of deforestation. In the late nineteenth century, forests covered about 52% of the country. By 1996, the forest cover had dropped to 20% before declining further to 13% in 2010. About 36% of the forest is within protected areas. While the highest deforestation is outside protected areas at an annual rate of 2.27%, forest cover within protected areas is also declining at an annual rate of 1.86%. Out of 111 districts, 28 have deteriorated forest ecosystems, while 19 districts have a remaining forest cover of less than 1%. The forest cover in the central region has been especially exposed and the only forest that remains is within protected areas.

Major causes of deforestation are due to urban settlements, agricultural expansion, grazing, logging and industrial growth. Some of the impacts of deforestation include: erosion of the topsoil and nutrient loss; decrease in water quality and quantity in dry periods; increased flooding in wet seasons; and decreased biodiversity and loss of habitat. A decline in the growth of agricultural food production from 1.7% to 0.9% in 2004/05 to 2005/06 has been linked to nutrient depletion due to deforestation, among other issues. Forest management is carried out by National Forestry Authority (NFA), Uganda Wildlife Authority (UWA) and the District Forest Service (DFS) under the guidance of the National Forestry Plan and Tree Planting Act (GoU, 2013*a*), and the Forest Policy (GoU, 2001). The implementation of policy and plans has been difficult due to a number of factors, including scarce financial resources and specialists, and poor farmer education.

Land degradation is a major challenge to Uganda's development. The highland and cattle grazing regions are severely affected. As much as 41% of Uganda's total area suffers from severe degradation. Another 12% suffers from very severe degradation. Generally, it is estimated that 4% to 12% of GNP is lost from environmental degradation, while 85% is lost due to soil erosion, nutrient loss and changes in crops. The cost of soil nutrient loss due to erosion is estimated at about US$ 625 million per year.

The worst affected areas, as shown in **Table 7.2**, include the south-western Highlands of Kabale (85%–90%), the eastern highlands of Mbale and Kapchorwa, (75%–80%) and the semi-arid rangelands of Rakai, Nakasongola, Moroto and Kotido, which are already facing desertification (NEMA, 2001). Of the many different aspects of land degradation, the main causes are: population pressure, poverty and land fragmentation, leading to over-exploitation of the land with inadequate soil and water conservation practices.

The government has put in place the National Soils Policy in 2004 and the Uganda Land Policy in 2001 (GoU, 2015). It is expected that effective implementation of these policies will result in a reduction of the rate of soil and land degradation in the country. In 2015, the government approved an implementation plan going into 2019, when it will be possible to assess the actions taken to comply with these policies (GoU, 2015*a*)

A study by Rwakakamba (2009), points out that environmental degradation in the country includes a critical situation of wetland encroachment and contamination of water resources. The study assessed the water situation in four mountainous districts of Uganda and evaluated the effectiveness of government policies with regard to restoration and conservation of water catchments. The study revealed a glaring gap between the existence of laws and policies on the one hand, and the reality of implementation on the other.

Photo 7.1. Coupled with a changing climate, population growth is a major threat, creating increased demands for water and land for agriculture and settlements.

Increasing rural population densities with few non-farm income opportunities; low investments in soil management and improvement; inadequate farmer knowledge on sustainable land management; and inappropriate farming practices, including deforestation, bush burning and overgrazing, make up the other environmental challenges that are being faced by Uganda (Olson and Berry, 2003; Zake et al., 1999; NEMA 2001; Kazoora, 2002).

Table 7.2. Estimates of the proportion of land affected by soil erosion in selected districts.

District	Total land	Soil erosion area		Population density	Main causes of soil erosion
	(ha)	(ha)	(%)	(people/ km²)	
Kabale	165 300	148 770	90	250	Population pressure, deforestation, poor farming
Kisoro	66 200	56 270	85	279	Population pressure, deforestation, poor farming
Mbale	250 400	200 320	80	282	Population pressure, deforestation, poor farming
Rakai	388 900	311 120	80	98	Vulnerable soils, poor farming, overgrazing
Kotido	1 320 800	990 600	75	14	Overgrazing, bush burning, vulnerable soils
Kasese	272 400	163 440	60	126	Population pressure, overgrazing, poor farming
Nebbi	278 100	166 860	60	114	Slopes, deforestation, population pressure
Moroto	1 411 300	846 780	60	12	Overgrazing, bush burning, vulnerable soils
Masaka	551 800	275 900	50	151	Slopes, population pressure, poor farming
Mbarara	1 058 700	529 350	50	88	Deforestation, bush burning, overgrazing

Source: Olson and Berry, 2003.

7.3.2. Loss of biodiversity

Despite its small size, Uganda is one of the richest countries in Africa in terms of biodiversity. This situation is attributed to its geographic location, varied landscapes, ecosystems and life forms. While the actual number is unknown, there is a provisional list of 18,783 species in Uganda. Astonished by this wealth and richness, Sir Winston Churchill, writing *My African Journey* in 1908 described this land as a 'Fairy Tale' and the 'Pearl of Africa'.

However, in 2004 the rate of biodiversity loss in the country was calculated to be 10–11% per decade, about 1% annually (WHO, 2017). Moreover, the decline of fish species in Lake Victoria is considered to be the largest documented loss of biodiversity ever inflicted on an ecosystem by humankind,[1] where 20 species of fish have been depleted in only the last 40 years, leaving just 3 species (Witte et al., 1999). Many major mammal species, such as rhinos, cheetahs and Oryx, were extirpated during Uganda's decades of internal strife in the 1970s and 1980s. Bird and fish species continue to decline in number and distribution throughout the country (WHO, 2017).

Major causes of biodiversity loss are: deforestation and over-harvesting and exploitation of other biological resources; population pressure and habitat degradation; encroachment and changes in land use; soil erosion; invasive alien species; oil and gas exploration in the Albertine rift valley; illegal exploitation and cross-border trade in natural products; and the impacts of climate change (NEMA, 2009).

1 www.aho.afro.who.int/profile_information/index.php/Uganda

7.3.3. Cultural diversity

Uganda is rich in both linguistic and ethnic diversity, which also reflects the use of its impressive bio-cultural diversity. Although a significant proportion of Uganda's biological diversity is still used by most Ugandans for the management and treatment of diseases (Bukenya-Ziraba et al., 1996), for a long time, the system has not paid due regard to its contribution. Such healthy biocultural systems provide a strong counter to the 'reductionist' effects of globalization and can create a refuge of biological and cultural wealth for Uganda.

There has been no in-depth enquiry or documentation with regard to the nature of existing biocultural diversity, and how this might be integrated into the different sectors of health, engineering and innovation. In reality, the custodians of most of Uganda's biodiversity are the rural poor, who are worst affected by the mismanagement of the country's bioresources. The interaction between nature and culture has often been left out of the mainstream debate on environmental management. There is a growing movement of individuals and organizations proposing innovative pathways of environmental sustainability reform in areas such as eco-tourism. Whether these new voices are heard by 2030 will depend on the quality of policy space given to these new narratives, the amount of funding and the human capacity mobilized for more sustainable pathways.

Uganda has one cultural and two natural sites inscribed on the World Heritage List (UNESCO, 2010), but their potential as a heritage resource, particularly for tourism, has not been fully optimized due to minimal investment and poor management capacity.

7.3.4. Climate change

Climate change will have a significant impact on Uganda. Studies (Markandya et al., 2015) show that if no adaptive action is taken, annual costs could be in the range of US$3.2–5.9 billion within a decade, with the biggest impacts being on water, followed by energy, agriculture and infrastructure, as shown in **Table 7.3**. A key impact among these is the estimated effect on Ugandan export crops of coffee, cotton and tea by 2050: 50–75% for coffee, with similar impacts predicted for tea and cotton. In addition, extreme events such as droughts have caused losses to agriculture in the recent past, in the range of 1–7% of GDP. If these become more frequent, as is likely, economic output in key sectors will be reduced, having knock-on effects in other sectors. These would represent a major impact on development.

Table 7.3. Summary of annual cost of inaction regarding climate variability and change 2010–2050 for Uganda (US$ millions)

	2025		2050		Total 2010–2050	
	LB1	UB1	LB	UB	LB	UB
Agriculture	293	513	1 401	2 458	22 200	38 300
Water	2 437	4 499	5 538	10 225	120 356	222 225
Energy	338	338	10 443	10 443	123 600	123 600
Infrastructure[2]	94	505	581	3 857	6 478	52 747
Total cost	3 162	5 855	17 963	26 983	272 634	436 872
As % of PPPGDP	3.01	5.57	2.31	3.48	2.80	4.49

1 LB/UB: Lower/Upper band estimates obtained from projections under SSP1/RCP4.5 and SSP5/RCP8.5 scenarios respectively
2 Loss in the capacity of infrastructure to withstand climate change.
Source: Taken from Markandya et. al., 2015.

7.3.5. Social and environmental sustainability impact of refugees in Uganda

Over the last 20 years, the Great Lakes Region has always been in the proximity of conflict caused by a complex network of political and economic interactions, with significant implications for peace, security and governance. As a consequence, waves of refugees have emerged from the enduring conflicts within this volatile region. Currently, Uganda is hosting about 1,252,470 refugees and asylum-seekers; it remains the largest refugee-hosting country in Africa and the third largest in the world (UNDP, 2017). By 2017, 72% of the overall refugee population in the country (excluding self-settled refugees living in Kampala) were hosted in the northern region, and the West Nile subregion.

Refugees mainly come from the surrounding conflict-affected countries like South Sudan (69.3%), Rwanda, Burundi and Somalia (6.8%), and the Democratic Republic of Congo (20.3%) (UNHCR, 2015). Such a wave of refugees has had a strong impact on the environment, as shown in **Figure 7.4**.

The cost of the refugee influx to the country has been difficult to determine but some estimates run it up to a third of a billion US dollars (UNDP, 2017). Heng et al. (2016 and 2017) have made an in-depth analysis of the economic impact, which includes a discussion of how in some community refugee farmers have created income spillovers when they hire labour from other households and purchase inputs from local businesses. However, while refugee integration has occurred in some communities, their net contribution to the local economy is still low.

To face the refugee influx, the government of Uganda has adopted and strengthened policies and laws with regard to receiving and granting asylum to refugees and their settlement in the country. Refugee management and protection is a centralized government function as per Article 189 (1), 6th Schedule, Item 5 of the Constitution. Refugee management and protection was included in NDP II and is premised in both international and national legislation, including the UN 1951 Convention, the 1967 UN Protocol and the 1969 OAU Convention. According to Heng et al. (2017), Uganda has one of the most favourable and progressive refugee assistance programmes in the world, with freedom of movement, work rights, and land officially set aside for refugees to farm.

Reversing environmental damage can be difficult. Some remedies are being explored to mitigate such damage, consisting mainly of attempts to define strategic interventions within refugee-hosting communities, and principally striving towards the collective engagement of such communities and their inclusion in local community planning, in order to help reform practices like fuel wood extraction from forests and unsustainable use of resources. Better information dissemination of new and appropriate technologies within such communities and awareness-building should also support sustainable environmental outcomes within host communities.

Forest-related impacts	Range-related impacts	Agriculture-related impacts	Water-related impacts
• Increased cutting of live trees for building material, fencing material, charcoal and for sale to urban markets. • Depletion of dry wood can lead to use of green wood as fuel. Increased competition over forest resources like roots, mushrooms, fruits, insects, rodents and others. • Traditional management systems of trees and forests can deteriorate. Official forest protection can be overwhelmed. • Reduced forest cover leads to increase of soil erosion by water and wind	• Overgrazing by refugee animals or herds attracted by refugee-related infrastructure. Reduction of range by fencing in large areas for agency compounds, afforestation schemes and by camps and settlements. • Reduction of range by expansion of agriculture. • Deterioration of range for browsing animals by timber harvesting, gathering of fencing material and fuel wood. • Garbage and chemicals pose threats to livestock health. • Loss of ground cover exposes soils to wind and water erosion.	• Fallow periods are shortened due to higher demand on land, cheaper labour, or ignorance of agricultural practices. • Lack of knowledge on the side of refugees leads to destructive farming practices. • Deforestation in the region threatens fields by wind and water erosion. • Unsuitable hillsides are cultivated. Support of agencies ('occupational therapy') leads to unsustainable or harmful practices.	• Over-use of surface and sub-surface sources by refugees, their livestock and agencies. • Contamination of surface water and shallow wells by human and animal faeces, detergents, pesticides and other chemicals. • Siltation of surface water collection structures due to overuse of banks, loss of ground and cover and vegetation loss in catchment area.

Figure 7.4. Summary of impact of refugee activities
Source: Elaborated by Steven Sebbale from various sources.

7.4. National policies addressing sustainability

Uganda has actively pursued sustainable development since the early 90s. This pursuit unfolded in three distinct transition phases/objectives: post war reconstruction (1986–1997); poverty eradication (1997–2009); and social economic transformation (2010–2020). Uganda's Vision 2040 sets the aspirations and strategies for the country's sustainable development (GoU, 2007). The achievement of sustainable development has been stressed by governmental policies over recent years, as it was recognized that for several decades, development had concentrated on the advancement of economic, social, cultural and political conditions and less on preserving the environment.

Further, as a political standing, the NRM Manifesto (NRM, 2016) recognizes the environment as a critical component of development and plans are proposed for increasing the country's forest cover from 10% to 15% by 2021. The NRM calls to prioritize the review of the Forest and Tree Planting Act (2003) with the objective of strengthening forest conservation and tree-planting initiatives. It considers sustainable management of natural resources as vital, mainly with the view to add value 'as a way of creating jobs and earning better revenue from them while also ensuring their sustainable exploitation for generations to come'.

In the above context, Uganda ratified the Convention on Biological Diversity in 1993 and the Cartagena Protocol on Bio-safety in 2001, and is implementing the National Biodiversity Strategy and Action Plan (NBSAP) of 2002 (NEMA, 2009). The National Environment Management Policy adopted in 1994, the National Environment Statute adopted in 1995 and the establishment of the National Environment Management Authority (NEMA) are now fully in place. The National Forestry Authority and Uganda Wildlife Authority are also in place. The Ministry of Local Government and the district local governments have mainstreamed environment and natural resources management into the performance measures at all levels.

Further, Uganda introduced a number of reforms and pieces of legislation that also address sustainability. Among the more important of these are (GoU, 2016): Public Finance Management Act (2015); Public Private Partnership Act (2015); Public Procurement and Disposal Act (2014); Financial Institutions Amendment Act (2015); and Registration of Persons Act (2015).

With the adoption of the 2030 Agenda by the UN in 2015, Uganda was among the first countries to integrate environment into the national planning frameworks. It was considered that the Agenda 2030 presented Uganda with an opportunity to refocus its own development agenda, and address the bottlenecks that hamper development, learn from, and network with other countries, and accelerate national efforts towards achieving a middle-income status, while pursuing sustainable and inclusive

development within the framework of the Uganda Vision 2040 and the second National Development Plan (NDP II).

To implement the country's own 2030 Agenda, several steps have already been taken that include: national and local level consultations; information, education and communication campaigns; high-level policy dialogue engagements; institutional capacity development; and revitalized engagement with the private sector and civil society. More specifically, the government has undertaken a number of reforms to improve institutional functionality and steer coordination and implementation of national development programmes. In order to enhance data acquisition and incorporate sustainability indicators in the national accounts, a National Standard Indicator Framework has been put in place. This framework builds on the National Monitoring and Evaluation Policy and the Integrated NDPII Monitoring and Evaluation Strategy.[2]

Rwakakamba's 2009 study observed that most existing laws and policies are conservationist in nature, and recommends the inclusion of restoration policies in all environmental policy regimes so that the already depleted environmental resources are restored. It also seems that, despite the formulation of a large number of policies to regulate land use and impacts on the environment, the alarming rate at which natural resources are being depleted shows that these laws and policies are not enforced effectively.

With a conducive policy, and with legal and institutional framework in place, Uganda's key challenge now is to adequately implement them through effective policy instruments. Also, it will be necessary to face the challenges of weak multisectoral implementation planning and coordination, data and reporting inadequacies, human and financial resource insufficiencies, weak public private partnerships and, in particular, the mobilization of all national actors around the development agenda.

7.5. Science, technology and innovation for development

7.5.1. The national innovation system

Figure 7.5 describes the national innovation system (the SETI organizational chart). The systems approach recognizes the diversity of actors and their inherent interrelationships to foster innovation that can provide the best opportunities for sustainable development (Ecuru, 2013). This is necessary for policy coherence among sectors to ensure coordinated cooperation between decision-makers that can ultimately build broad ownership for sustainable outcomes. The approach helps to overcome the linear model of innovation that has been dominant in African policy.

The SETI organizational chart shows the distribution of responsibility for implementing a given policy. In the chart, there are five distinct levels:

a) Policy-planning level (policy design).

b) Promotional level (funding).

c) Performance level (scientific research, technological development and productive innovation).

d) Science and technology services.

e) Assessment/evaluation level.

Uganda's innovation system engages both public and private sectors as key stakeholders in the creation and use of new knowledge, although, as will be discussed later, it is noted that policy still falls short of providing the necessary space for interaction within the system.

7.5.2. Governance of the innovation system

The Uganda government established the National Research Council (NRC) in the early 1970s with the mandate for research oversight, advising on national research policy and as a research-funding agency. The institutional construction in Uganda followed several regional and international plans, and strategies such as the Monrovia Declaration of 1979 and later the Lagos Plan of Action (LPA) in 1980 (OAU, 1985). In 2005, NEPAD adopted Africa's science and technology Consolidated Plan of Action (CPA) to provide a regional framework for harmonization of STI development (AUC, 2005), through a systems approach.

Uganda's governance of the innovation system underwent several reforms as part of the structural adjustment and economic recovery processes that occurred in the late 1980s and early 1990s. In 1990, the Ugandan government, by an act of parliament, created the Uganda National Council for Science and Technology (UNCST) as an agency under the Ministry of Finance, Planning and Economic Development, in order to replace the NRC and to address the crosscutting nature of STI and its role as an integral part of socio-economic and development planning.

Today, UNCST coordinates the research activities of all sectoral research institutions by virtue of its broad and overarching mandate. The mandate to coordinate the development and implementation of policies and strategies for integrating science and technology into the national development process

Uganda national innovation system

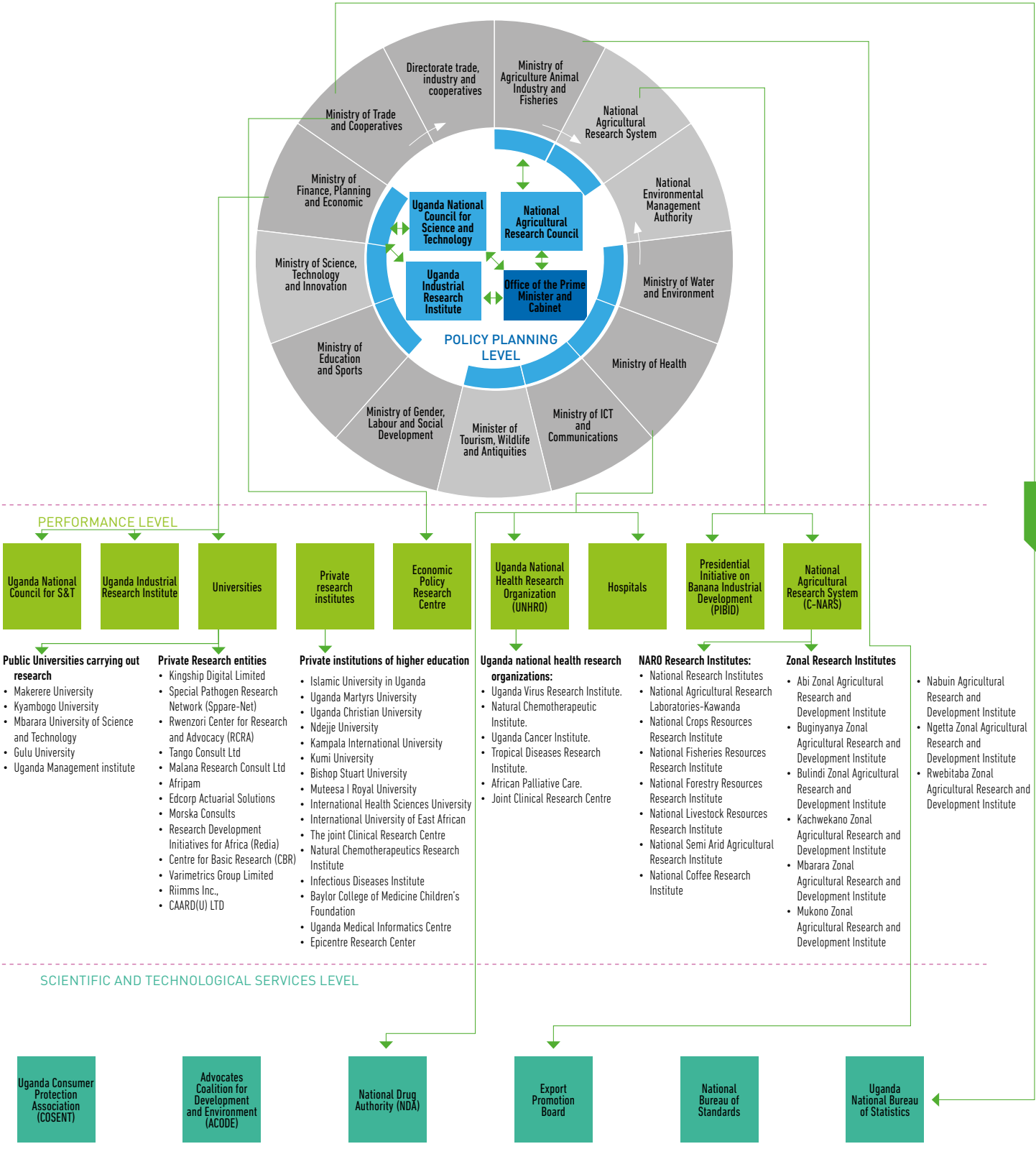

Figure 7.5. Organizational chart showing Uganda's research and innovation system.
Source: Authors' production based on GO→SPIN methodology (UNESCO, 2015)

covers all aspects. The functions of the UNCST include *inter alia*: coordinating the formulation of explicit national science and technology policies, developing strategies and programmes for advancing STI, and facilitating the conduct of research and development.

UNCST has also been coordinating policy aimed at shortening the cycle of technology mastery and knowledge, and enhancing technology. This has been done by finding ways to infuse knowledge into existing industries – an approach widely considered as effective by groups that analyse development (Brar et al., 2010). The Council, over the years, championed the development of a series of policies including the National Biosafety and Biotechnology Policy, the National STI Policy and the National ICT Policy, among others. With support from the World Bank, the Council also supported researchers and research teams under the Millennium Science Initiative and built capacity for research management and oversight.

In an effort to address some of the challenges in Uganda's STI governance and coordination system, the government established a dedicated Ministry of Science, Technology and Innovation (MoSTI) in June 2016, made operational in January 2017. The mandate of the ministry is to provide overall policy guidance and coordination for scientific research, development and the whole national research and innovation system. This reform in the STI sector is therefore expected to streamline the coordination of the system and make more explicit links and interdependencies between actors and institutions.

The creation of the ministry is meant to recalibrate the development, coordination and performance of STI policy imperatives in Uganda. The new ministry represents a structural reform that should transform the national system, legal framework and incentive structure for research and innovation, and should ultimately harmonize Uganda's long-term goals for the STI sector and foster R&D financing. Specifically, the ministry should facilitate research and innovation, promote techno-entrepreneurship, regulate STI and give sharper focus to the government's STI agenda through the support of targeted interventions like innovation support, research quality assurance and sustainable funding.

In addition to the creation of the ministry, the president issued the 23 Strategic Guidelines and Directives as minimum standards for Uganda to attain middle-income status by 2020 and vigorously implement its political manifesto of 2016–2021 (NRM, 2016). These presidential guidelines provide strategic directions on specific interventions through which science, technology, engineering and innovation (STEI) can contribute to achieving the desired growth trajectory in the medium term.

The Government of Uganda, recognizing information and communication technology (ICT) as one of the key drivers of the economy, created a dedicated Ministry of ICT in June 2006 and established the National Information and Communication Technology Authority of Uganda (NITA-U).

7.5.3. STI policy

The national STI Policy of Uganda has generally followed the ten-year STI strategy for Africa, STISA–2024, adopted by the African Union Heads of State and Government Summit in June 2014 (AUC, 2014). STISA–2024 places STI at the epicentre of Africa's socio-economic development and growth. The strategy is part of the long-term, people-centred African Union Agenda 2063 (AUC, 2015), which is underpinned by STI as a multifunctional tool and enabler for achieving continental development goals.

The African Union adopted Agenda 2063 (AUC, 2015) and committed to achieve its vision of 'An integrated, prosperous and peaceful Africa, an Africa driven and managed by its own citizens and representing a dynamic force in the international arena'. The AU agenda emphasizes that Africa's sustained growth, competitiveness and economic transformation will require investments in new technologies and innovations in areas such as education, health, agriculture and clean energy.

In this context, the government of Uganda has adopted political declarations and policies, plans and strategies for sustainable development, and considers that STI is essential to the achievement of Uganda's National Vision 2030 and successive development plans. The strategic role of STI development in uplifting other sectors of the economy such as agriculture, industry, health, energy, education and environment has been vividly highlighted in the five-year national development plans (NDP II: 2016/17–2019/20) (GoU, 2015*b*); the NRM manifesto (2016); the 23 presidential strategic guidelines; the National Science, Technology and Innovation Policy (GoU, 2009); the STI strategy for Africa (STISA–2024); the Sustainable Development Goals (Agenda 2030); and the recently-adopted Paris Agreement on climate change (COP 21).

In 1994, the government, through UNCST, and in collaboration with various stakeholders, embarked on the formulation of a national STI policy, which was subsequently adopted in 2009 (MFPED, 2009). Before 2009, undertaking research in Uganda was guided by a plethora of sectoral policies spanning different agencies. Policies for research were sector-based and scattered within and across different entities, with no explicit research policy to guide the national discourse on priorities. As already noted, several international and national policies and

development frameworks informed the development of the national STI policy.

The STI policy aims at enhancing the contribution and role of STI in the national development process, as highlighted in Vision 2040 and the National Development Plan. It underlines the contribution of innovation and research in transforming Uganda into a knowledge-based economy and articulates the government's intent to foster research and development that builds the human capital required (Brar et al., 2010). The STI policy also aims to strengthen national capability to generate, transfer and apply technologies, and to ensure sustainable utilization of natural resources for the realization of Uganda's development objectives (MoFED, 2009).

The policy is anchored around four key objectives:

1. Creating an enabling policy environment to foster STI and augment its contribution to national development;
2. Building STI sector capacity to generate and transfer technology;
3. Establishing and strengthening the legal and regulatory framework to ensure ethics and safety in STI development; and
4. Application and strengthening of the STI coordination framework to enhance sector performance.

The policy seeks to create an enabling environment to foster STI and augment its contribution to national development by undertaking technology forecasting, assessment and transfer; industrial development; intellectual property management; traditional, conventional and emerging technologies; and promoting gender equality and equity. By improving public awareness and appreciation of STI, building an information management system and sector coordination and partnerships, the policy seeks also to strengthen the STI coordination framework, which is expected to enhance the sectors' performance.

The policy also addresses gender and equity by striving to promote active participation of all women and men, youth, children, the elderly and other disadvantaged or special needs/marginalized groups, and leverages private sector participation and investment in science and technology.

The government, within the provisions of the set policy, continuously monitors and assesses STI sector performance based on measurement parameters, as provided for under the relevant STI policy statements and the National Integrated Monitoring and Evaluation System (NIMES) framework. In the course of implementing the policy, a well-defined information management system, with reliable STI indicators and statistics that facilitate performance monitoring and affect evaluation over the short, medium, and long terms, has been created. The results of this monitoring and evaluation are available regularly in reports on the status of the STI sector, which inform STI policy.

7.5.4. The National Plan for Science, Technology and Innovation (NSTP)

The purpose of the current plan (2013/2014–2017/2018) is to facilitate the achievement of Uganda's development aspirations which include *inter alia*: lifting the population out of absolute poverty through provision of basic human needs, transformation of the economy from an agrarian to an industrial and knowledge-based economy, and enhancing Uganda's participation in global trade and development processes. The NSTP builds on existing initiatives in the various sectors to guide Uganda's development path towards achieving the national vision for STI. Essentially, the NSTP translates the national STI policy into strategies, actions and measurable results within a five-year dispensation, over four stages:

Stage 1: Sector problems and opportunities are identified, mapped and prioritized.

Stage 2: Determination of talent, knowledge, skills technologies and institutions required to address problems and opportunities.

Stage 3: Technology evaluation, selection, transfer, development and pilot testing.

Stage 4: Technology business incubation, commercialization and societal application.

The plan recognizes four key drivers that are critical to the operationalization of the four-stage STI development:

a) An enabling STI policy and regulatory environment, e.g. for strengthened coordination and performance monitoring and evaluation.

b) A competent critical mass of scientists/technologists and entrepreneurs to champion the technology value chain.

c) An appropriate institutional infrastructure framework for supporting the technology value chain.

d) Appropriate/adequate investment in STI development (resource budget).

In the short term, the plan prioritizes the creation of a science and technology fund, improvement of public appreciation of and support for science and technology, establishment of science parks and science centres, establishment of STI management systems, strengthening the intellectual property management

system and strengthening the institutional capacity of UNCST. Some of these goals are still to be reached.

In the medium term, the plan is expected to focus on increasing science and technology financing, human resource capacity-building, establishment of centres of excellence, strengthening research and development infrastructure and ensuring excellent quality standards capacity.

In the long term, the plan has called for the government to align its policies with regional and continental priorities, develop a code of ethics for science and technology, and provide a conducive environment for evolution of a science and technology culture along with infrastructure development. The implementation of the plan was expected to occur within a framework of collaboration with a cross section of stakeholders, guided by the mandates and primary responsibilities of their respective ministries, departments and agencies (MDAs), private sector institutions and civil society organizations.

Further, the two key outcomes for the STI sector by 2019/2020 are articulated in NDP II (2015/16–2019/2020), and are given as:

- Improve Uganda's Technology Achievements Index (TAI) which is expected to increase from 0.15 in the marginalized group of countries to 0.21, placing Uganda in a dynamic adopters group.
- Enhance R&D intensity by raising gross domestic expenditure on R&D (GERD) from 0.34% to 1%, as recommended by the African Union and a key milestone for STISA–2024.

7.5.5. Main actors in the national research and innovation system

The Uganda national innovation system is composed of a large set of actors, as already identified in the SETI organizational chart above. Some of the most important are described and analysed here.

Higher education

A highly educated human resource is a key condition for the appropriate operation of the national innovation system. In Uganda, the higher education system has grown tremendously since 1990, consistent with a similar global growth. This growth has however been uneven, concentrating in universities, leaving little room for other institutes such as technical colleges, which traditionally play critical roles in STI training. **Table 7.4** shows enrolment by gender in higher education institutions.

Table 7.4. Enrolment in Ugandan higher education institutions 2011–2012

Institutions	Number	Enrolment male	Enrolment female	Total	% of total institutions
Universities	32	78 817	61 270	140 087	71.3
Business institutes	58	12 260	12 724	24 984	12.7
National teacher colleges	7	4 989	2 853	7 842	4.0
Health care institutes	21	3 924	3 564	7 488	3.8
Management institutes	12	2 293	3 179	5 472	2.8
Technical colleges	5	2 914	336	3 250	1.7
Agriculture, fisheries and forestry institutes	3	1 169	456	1 625	0.8
Others[1]	27	3 889	1 753	5 642	2.9
Total	165	110 255	86 135	196 390	100

[1] Media institutes, theology colleges, law institutes, cooperative colleges, tourism institutes, arts institutes, aviation institutes, meteorological institutes, survey institutes.

Source: National Council for Higher Education, cited in UBS, 2014*b*, p. 18.

From the perspective of research and innovation, it is noted that enrolment in STEM programmes is still below 25% for all universities. Teaching is the main focus of most universities in Uganda, although research capacity is growing in a number of public universities. Furthermore, the collocation of public universities in the various regions of the country, and an emphasis on STEM education, may in the long term have a positive influence on the local innovative activities of surrounding firms and communities.

The country's vocational and technical institutes train students in technical skills needed in industry. Scientific research activities are undertaken in several places, but predominantly in Makerere University in Kampala, Kyambogo University, Mbarara University of Science and Technology in Mbarara and Gulu University.

The strong growth in the number of tertiary graduates has not translated into a great number of researchers. The total head count of researchers in Uganda is less than 3,000, i.e. one researcher for every 12,300 people (see **Table 5** below). Moreover, the increase in the number of universities is predominantly in arts and humanities, with very few private universities offering STEM-related disciplines.

The research efforts undertaken by universities concentrate on the health and agricultural sciences. The problems pertaining to climate variability, human disasters, pollution and other emerging challenges receive very little research

funding. Although universities are meant to provide answers to such critical issues facing the country, the limited research funding and weak research capacity has led most universities to concentrate on teaching with a weak research profile. Few universities in Uganda have explicit research policies and the little research being conducted in the higher education institutions is largely donor-financed. In addition, research is undertaken mainly as an end rather than as a means to provide solutions that other actors demand.

Research programmes that address industrial needs are undertaken at the Uganda Industrial Research Institute (UIRI), which has more than two decades of successful research implementation and outreach, and which has made significant efforts to boost its work with key industrial sectors, including textiles, food processing and material science such as bamboo production. The UIRI provides incubation services for innovators while universities provide the backbone to STI human capital requirements.

The National Agricultural Research Organization (NARO) carries out research and extension services in different institutes spread all over the country and has been conducting research and outreach for several decades. In comparison to the public sector, very few private sector institutions conduct research, with the majority of those that do so being foreign direct investors seeking to improve exportable products and build markets. Uganda has made improving the record of industrial innovation and research capacity a primary goal of the nation's STI policy (MFPED, 2009).

Other key institutions include the Uganda National Health Research Organization (UNHRO) and its research institute. Other civil society groups like the Uganda National Academy of Sciences (UNAS) also routinely provide insights to Uganda's STI policy agenda.

Human resources in the national innovation system

In in its last (published) R&D study and survey, UNCST (UNCST, 2013; UNCST, 2012) has provided a set of important indicators related to human resources in the national innovation system, following the Frascati Manual, as shown in **Table 7.5**.

Table 7.5 shows a large number of researchers in the business sector, an indicator that differs from many other developing countries in all regions of the world. Although yet to be studied in more detail, the presence of this number of researchers in the business sector is probably responsible for the high number of declared innovations, as identified in the UNCST survey for the period 2011–2014 (UNCST, 2017). Ecuru et al. (2012) and Ecuru (2013) have emphasized the structure and dynamics of Uganda's innovation system and noted its existing potential.

Table 7.5. Human resources in the national innovation system of Uganda by 2010

Indicator	Sector	Value (2010)
Total researchers (headcount – HC)	Government	2 823.0
Total technicians (HC)	Government	922.0
Total support staff (HC)	Government	525.0
Total researchers (full-time equivalent – FTE)	Government	1 262.7
Total technicians (FTE)	Government	447.9
Total support staff (FTE)	Government	296.0
Female researchers as percentage of total (HC)	Government	24.3
Female researchers as percentage of total (FTE)	Government	26.3
Total researchers (HC)	Business	1 431.0
Total researchers (FTE)	Business	639.0
Total researchers (HC)	Higher education	880.0
Total researchers (FTE)	Higher education	325.0
Total Ph.D. and post-doc students (HC)	Higher education	474.0
Total Ph.D. and post-doc students (FTE)	Higher education	39.0
Total researchers (HC)	Non-profit	108.0
Total researchers (FTE)	Non-profit	34.4

Source: Authors, from UNCST, 2013 data.

The National Innovation Survey 2011–2014 was conducted by UNCST in collaboration with the Uganda Bureau of Statistics (UBS). The survey followed the OECD Oslo Manual (OECD/Eurostat, 2005). The survey collected information about product and process innovations, organizational and marketing innovations and other key variables. The majority of the data referred to technological innovation; new or significantly improved goods or services; the implementation of new or significantly improved processes; or ongoing/abandoned innovation for products and processes.

The survey sampled 589 business establishments employing 10 or more persons from a total population of 6,475 business enterprises in the industry and services sectors during the reference period. The survey registered a response rate of 90.5%. Successful technological innovation activities were reported in 77% of the enterprises, of which 48.2% of were engaged in 'product and process' innovations, while organizational and

marketing innovations were reported by 72% and 69% of the enterprises respectively.

Financing R&D in the national innovation system

Table 7.6 provides an overview of the state of research funding in the country in 2010 (latest data published).

Table 7.6. In-house R&D expenditure by sector

Sector	Ugandan shilling* (millions)	Percentage
Government	75 138.9	38.6
Business	67 722.0	34.8
Higher education	49 482.0	25.4
Private non-profit	2 426.4	1.2
Total	194 769.3	100

* In 2012: 1 US dollar = 2,505.12 Ugandan shillings.
Source: UNCST, 2013

According to the data obtained by the R&D survey, GERD corresponds to 0.50% of GDP. The Innovation Survey (UNCST, 2017) reports that the country's GERD amounts to 0.34% of GDP.

In addition to current financial commitments to research, the government is making operational an STI fund with a target of up to 1% of GDP over the medium term, to finance scientific research and innovations of strategic national importance; acquisition of intellectual property rights by local innovators; and recognition of scientific excellence among local scientists.

Because of limited public funding and almost none from the private sector, research in the higher education sector derives funds from several sources, mainly international donors. An evaluation conducted by the World Bank (2016) shows the difficulties of financing higher education research in the country, as more than 50% has its origin in foreign sources and that in the period 2013/14, higher education institutions spent a dismal 0.75% of their total expenditure on R&D.

This funding pattern inevitably affects the type of research performed by these institutions. In Uganda, the absence of explicit funding from government research institutions has resulted in fragmented, ad hoc, time-bound research which may not be consistent with sustainability science (Brar et al., 2010).

Consistent with the STISA–2024, Uganda has taken some bold steps to indigenize research funding at a local level by establishing several mechanisms. The Presidential Support to Scientists (PSS) programme under the UNCST is a flagship programme to support scientists conducting last-mile research and development geared towards bringing products to the market. The president's support has been evident through funding creative programmes at Makerere University, such as the electric Kiira EV motor vehicle, and through developing value-added products by the Colleges of Agriculture and Environment and of Veterinary Medicine. Prototypes have been developed, some patented, also through the president's initiative. Scaling up these prototypes into commercial products remains a challenge, however.

Recently, more regional initiatives like the Bio-innovate programme have also emerged to support collaborative research teams in value addition for bio-resources, crop productivity and biosciences across six different countries in eastern Africa, including Uganda.

The establishment of a National STI Fund in the early 2000s is also a result of the recognition of the role of research and innovation in the development process. The fund is expected to accelerate product commercialization in priority areas of science and technology. Anther initiative is the creation of the Millennium Science Initiative (MSI) (Brar et al., 2010), the main pioneering funding facility that supports research and is a catalyst for the creation of interdisciplinary research teams that include both junior and senior researchers.

Linkages of universities with different actors in the national innovation system

Within today's government efforts to enhance entrepreneurship capacities in the private sector, universities – in particular Makerere University – are concentrating principally on developing entrepreneurial activities and efforts to improve university-industry-government links. One such effort is that of Makerere University, through the Innovation Systems and Clusters Programme, which has been able to establish and work with more than 50 innovative clusters in different sectors of trade. Makerere University is also conducting a M.Sc. programme – Technology Innovation and Industrial Development (TIID) – at its College of Engineering, Design, Art and Technology, as an effort to enhance industrial innovation.

Inter-university collaboration is poor overall, as most universities are generally inward-looking. There is a very limited interface between individual disciplines, with research often conducted in silos and academic research often being viewed as an end rather than as a means or tool that can inform the policy process or impact on socio-economic goals. This situation limits opportunities for inclusive, transdisciplinary and solution-oriented research.

Despite the weak linkages of universities with other actors of the innovation system, there is an emerging culture of engaging in virtual knowledge spaces by young researchers. Such networks are increasingly facilitating the sharing of scientific information in a growing research system. The creation of networks of scientists, STI think tanks and research-funding platforms for collaboration should help the adoption of a common strategic research agenda that can develop knowledge and innovative solutions for sustainability.

Indigenous knowledge

Uganda is facing societal challenges that require indigenous and local knowledge contributions. The interaction of indigenous communities and their accumulated know-how in environmental management is critical to any policy debate on sustainability. The impact of climate change and the traditional coping mechanisms employed by those communities is inextricably linked to the dynamic narratives of adaptation, knowledge generation and management. In Uganda, indigenous knowledge (IK) has long faced negative publicity that is mainly embedded in cultural prejudice. The wealth of knowledge on medicine, crop management and weather forecasting, among other areas, presents an often missed 'body of evidence' that can inform sustainability approaches. As early as 1998, UNCST made a formal declaration where it recognized the role of IK systems and benefit sharing between IK custodians and other counterparts (Tabuti and Van Damme, 2012).

7.5.6. Assessment of the system

In an effort to further understand Uganda's STI policy environment, Brar et al. (2010) undertook an analysis of the Ugandan innovation system, using a novel methodological framework adapted from a heuristic tool dubbed the 'National Innovation Systems Framework'. The new methodology, known as THICK (Technology, Human Resources, Institutions and Infrastructure, Collaboration and Communications, and Knowledge), focused on the functions of a science and technology system that makes knowledge useable.

The study reported that despite the relatively small size of the investments made in science and technology, the past few years had seen considerable advances in building capacities, developing STI-related institutions and human resources, advancing collaboration and communication, and expanding the base of available knowledge. The study proposed that given Uganda's limited investments in science and technology, policies should prioritize near-term investments that benefit key sectors. Subsequently, near-term investments as well as longer-term ones (three to five years in the future) were identified.

The study by Brar et al. (2010) also notes that a weak STI governance system and a loose national research and innovation system with disparate and often uncoordinated actors have weakened the potential contribution of STI to national development. The understanding of a linear innovation processes has also resulted in a fragmented innovation system with limited opportunities for critical networking among the different actors in the STI system. Since each of these functions is usually the subject of its own dedicated ministry with its own mandate and mission, it is often quite challenging to pull all of them in the same direction to support innovation.

Ecuru and Kawooya (2015) have conducted an extensive and detailed analysis of the situation of research and innovation in Uganda, in the framework of the Global Innovation Index (GII), and as such concentrated on the indicators that measure

Photo 7.2. The sources of the Nile

innovation. The main results of this analysis show that there has been progress in innovation, as measured by the index, and that this is the result of nearly 30 years of consistent and relatively predictable socio-economic policies aimed at transforming the country from a peasant society to a middle-income economy by the year 2040.

So far, Uganda's development strategies and policies have emphasized innovation through science and technology capacity development for various core sectors, including manufacturing and agro-processing, which are growing. That growth partly explains Uganda's recent improvement in GII rankings. Further, it is noted that Uganda's GII ranking may improve if the government sustains the momentum it has created – for example, through initiatives such as the National Innovation Fund (US$0.2 million) in the period 2003–04, the Presidential Support to Scientists (US$4 million) in the period 2006–14, and the Millennium Science Initiative Project (US$33.35 million) in the period 2007–13.

The study also notes that although Uganda has numerous policies relating to research and innovation, its challenge is to get a policy mix that is synergistic and creates an environment conducive to learning and interaction among actors in the public sector, private businesses and civil society.

There are other characteristics of research and innovation in Uganda that need to be reviewed. The research being conducted is often basic with no real application potential or relevance to the prevailing policy environment. The participation of academia in policy processes is limited by the nature of research they undertake (devoid of policy orientation), their limited interaction with policy-makers or their inherent disinterest in the politics of policy-making. There are of course instances of collaboration between the policy formulation apparatus in government and specialized research institutes and lobby groups within the university system. The Economic Policy Research Centre (EPRC), Makerere Institute of Social Research (MISR) and others are cases in point.

The donor-driven research agenda in Uganda limits opportunities for transdisciplinary and solution-oriented research. The absence of 'knowledge communities' across the different fields of science and technology has made it difficult to conduct transdisciplinary research. This is mainly because fields of science are only appreciated in their narrow sense and the need for a multidisciplinary approach has not been a requirement when applying for grants and other forms of research funding. As a result, most of the research undertaken in universities is more of an end rather than a means to address the complex challenges of sustainable development (Spanenberg, 2011).

The success of STI interventions in ensuring environmental sustainability hinges on the interaction between science policy and society. Most sustainability research includes a diverse array of stakeholders, which may include NGOs, academia, communities and governments. The existence of an institutionalized architecture to foster this interaction is critical to ensure that all actors, including communities, civil society, indigenous people, academia and research institutes have the information they need. For Uganda, the issue rests on the quality of such connections, which matters with regard to the degree to which stakeholders have the capacity to respond to change (Pahl-Wostl et al., 2008).

7.6. Research and innovation for sustainable development

Uganda is making efforts in deploying sustainability science to respond to sustainable development challenges. Three especially successful cases are reviewed here.

7.6.1. Case study 1: Malaria prevention at household level using a beverage blended from artemesia, annua, avocado powder and lemon grass

This is an outstanding contribution to sustainability in the area of healthcare. The innovation is based on the artemisia-annua anti-malarial beverage – Artavol – where medicinal plants have been converted into an antimalarial product with pharmaceutical characteristics. Artavol was developed by a Ugandan pharmacist in collaboration with scientists at the Natural Chemotherapeutics Research Institute Laboratory and Makerere University.

This innovation was conceived to address the widespread and devastating effects of malaria, using a readily available and marketable beverage – tea – to deliver the solution. The project explored the outcome of the use of an avocado powder-lemon grass blend herbal beverage for malaria prevention and eradication at household and community levels. In the research conducted by the team, it was found that after eight months of taking the beverage, subjects did not develop any fevers associated with malaria. Among the study participants, hospital visits for fever-related causes fell by 80% as compared to the control subjects, who visited hospital more often for fevers related to malaria.

Artavol has been patented with the African Regional Intellectual Property Organization and is currently produced and widely distributed through pharmacies and drug shops in Uganda. In 2014, the Ministry of Health in Uganda recognized the innovation and presented an award to the principal investigator for outstanding achievement in research for herbal prevention of malaria.

Artavol production currently stands at 6,000 100g tins per month. Distribution is mainly through pharmacies, exhibitions and during school visits to raise awareness about the product. In the international market, it has been sold to Ghana with orders received from Niger, Mozambique and Senegal, which could not be fulfilled due to prohibitive freight costs. Moreover, this large-scale shipping would require licensing the product in those countries as a medicine for malaria control, which is a difficult process.

In order to address the high costs of equipment, the Artavol programme has a collaborative arrangement with alumni from the Makerere University College of Engineering Design, Art and Technology to fabricate production equipment. Besides controlling malaria, a significant outcome of this innovative endeavour is a new discovery that regular consumption of artemisia among HIV/AIDS patients increases resistance.

In terms of sustainability, the Artavol concept has evolved into a Centre for Science-driven Traditional Medicine and Drug Development at Mbarara University of Science and Technology. The centre is sponsored by the Government of Uganda and World Bank under the auspices of the African Centres of Excellence for Southern and Eastern Africa (ACE II).

The objective of this initiative is to train and build a critical mass of graduate scientists specializing in traditional medicine and pharmaceutical biotechnology, and to link traditional medicine research outputs to industry in the region. It is envisaged that at the end of 5 years (i.e. by 2022), 30 Ph.D.'s will have been completed; new drugs will be discovered and developed; 60 masters students will add scientific and economic value to traditional medicine; 500 herbal medicine producers will be trained through short courses to improve the quality, safety and efficacy of their herbal products; and 5,000 traditional medicine practitioners will be trained to improve primary healthcare service in the region. The innovation has therefore unveiled enormous opportunities for transdisciplinary research that integrates indigenous traditional knowledge.

7.6.2. Case study of the production and application of *Phytolacca Decandra* to control vector-borne diseases

The project set out in the 1990s to promote the production of Phytolacca Decandra, a locally abundant unutilized wild plant, as a natural biodegradable and environmentally safe product to control fresh water snails and other vectors like mosquitoes. It was inspired by earlier work at the Institute of Pathobiology, Addis Ababa University, on the successful use of Phytolacca Decandra to control bilharzia in Ethiopian communities.

Photo 7.3. Phytolacca Decandra

The project tested Phytolacca Decandra (Omuhoko/Luwooko, as locally known in Uganda), for its effectiveness and subsequently developed Snailtox – a potent insecticide for the containment of snails that cause bilharzia in humans and liver flukes in livestock. It has been scientifically proven to be an effective molluscide against freshwater snails – the vectors for liver fluke in cattle. It has also been used to control Biomphalaria snail – vectors of bilharzia in humans.

To process the molluscide from Phytolacca Decandra, mature but unripe berries of the plant are harvested, dried and milled into a powder under the commercial name Snailtox. The powder is soaked in water for 12 hours. The extract is then used as a molluscide. It is applied in predetermined amounts to give a final concentration range of 15–20 parts per million in water dams and ponds infested with snails. Repeated applications of this extract eliminate the snails, and Snailtox is now commercially used to control liver flukes in cattle – already saving cattle farmers millions of shillings.

Besides being affordable, it easy to apply and environmentally safe. It controls snails that transmit bilharzia (larvae of anopheles mosquitoes) which transmit malaria, and vectors that transmit river blindness, in addition to other unexplored applications. The project is now promoting the planting of Phytolacca Decandra against the common trend of planting eucalyptus and other exotic trees. The project has sought to engage the community through a model where community members grow and sell Phytolacca Decandra to the project for processing into Snailtox.

7.6.3. Case study of MakaPads sanitary pads

The MakaPads project, conducted by the College of Engineering, Design, Arts and Technology of Makerere University[3] was inspired by the results of a study which revealed that academic performance of most girls dropped at puberty level and there existed a high rate of absenteeism from school among poor schoolgirls. This was due to an inability to access affordable sanitary towels during menstruation. For many girls in the rural areas, menstruation therefore means no school. The innovation and products from MakaPads have met this need by providing an effective, low-cost protection to the girls. The goal of this intervention was to develop an environmentally friendly, affordable and appropriate innovation – MakaPads are produced using recycled paper products and local papyrus plants, which act as a natural absorbent when processed. Using these local products helps keep costs low, as no imported materials are needed.

The pads are fitted with a mesh covering for comfort and come with the option of an adhesive strip that helps fit into undergarments. After packaging, lights are used to help sterilize the materials and ensure that they are safe for personal use. All of the electricity used in production of the MakaPads is produced through solar power, which contributes to their sustainability. The community is involved in harvesting and processing the papyrus, thereby earning income, which allows them to support their families. No specific skills are needed, and the women receive all the necessary training, which helps create a sense of importance and responsibility.

MakaPads are currently distributed in both Uganda and Sierra Leone, with hopes of expanding. They are produced at a low cost, which makes them easily affordable for the women who use them, with a pack of 10 costing US$0.53. Since they are completely biodegradable, women are also able to easily dispose of them after use. The innovation therefore addresses the challenge of disposal and poor degradability of sanitary pads and diapers. The process of producing Makapads itself is innovative, as people can work at home and only have to take the final product to the factory for packaging to ensure quality and delivery on schedule.

The next stage of the plan is the industrialization of baby and adult diapers using MakaPads technology and production methods (appropriate technology). The diapers have been tested and found not to cause diaper rash or skin irritation because they are free of chemicals. Further, they do not swell after absorbing liquids and the natural absorbents used make them the only biodegradable diapers in the world, giving them great export potential.

7.7. Conclusions

A review of the status of Uganda's development indicators shows that although the country has made significant progress in socio-economic development, it still lags behind in many areas as compared to the countries in this study. However, the country is endowed with significant natural resources which *inter alia* include fertile soils, minerals, flora and fauna as well as oil, which was recently discovered in significant quantities and is expected to positively impact the development of the country.

Uganda faces challenges in its transformation towards sustainability, owing to an institutional lack of capacity to align the different interconnected socio-ecological systems. The current research system does not properly describe the complex interdependencies of research being conducted. Moreover,

3 www.cedat.mak.ac.ug/research/maka-pads/

research may not be readily informed as to the current problems of environmental change and sustainability, or those that relate to social and cultural diversity.

Government political declarations and policies, plans and strategies for sustainable development consider that STI is essential to the achievement of the National Vision 2030 and the successive development plans. It is noted, however, that most objectives and goals of the ongoing national policy and plan for STI are addressed more to meeting the economic elements of innovation and development, and lack not only an in-depth view of sustainability and inclusion challenges, but also funding and specific and effective implementation measures.

Uganda is evidently making progress with respect to building innovation capabilities in both the public and private sector. However, a policy mix that promotes innovation and creativity in universities and firms is still needed. The rapid growth of universities is an opportunity to harness young talent by supporting creative work, research and innovation. Of particular importance is defining a clear and ample financing policy for research and innovation.

The evolving nature of sustainability science has an effect on the character of STI governance. Improved STI governance can foster improved partnerships between STI actors. While scientists, researchers, indigenous and local knowledge-holders and innovators can provide learning, they also rely on complementary interaction with other actors and institutions that are not necessarily engaged in science and technology but provide critical elements of the knowledge system.

Given the evolving nature of sustainability science, scholars, policy-makers and planners, and societal actors in Uganda need to promote the concept and develop capability for transdisciplinary research, in order to address some of the intractable sustainability challenges. There is also the need to mainstream transdisciplinary research into the national education and research systems.

In order to address the weak research/academia, society and private sector linkages, it is recommended that Uganda consider putting in place incentive mechanisms to encourage the active participation of the private sector and societal actors in the co-design of knowledge and sustainable solutions to the country's challenges. This will also reduce dependency on external aid and facilitate a truly endogenous agenda for national development, with a specific focus on its natural resources.

The development of STI in Uganda requires the upgrading of science laboratories and the establishment of world-class infrastructures. Although the African Union is encouraging member states to build the necessary infrastructure to leverage STI for sustainable socio-economic development (OECD, 1989), Uganda's level of STI infrastructure is inadequate to facilitate STI-driven development (MoFED, 2009). As a result, Uganda's innovation system is fed by a limited number of research infrastructures to facilitate the creation, transfer and application of knowledge. This often results in outsourcing of Ugandan research activities to other countries where such infrastructures exist, thus impacting on research sustainability.

In spite of continued weaknesses in the socio-economic innovation relationship, Uganda is making commendable progress towards harnessing sustainable solutions, as demonstrated in the case studies on malaria/mosquito, livestock disease control and sanitary pad technology. These innovations are primarily drawn from indigenous knowledge that has been shaped through iterative interactions between the communities and their environment, and have facilitated a sustainable process. Evidently therefore, Uganda's nascent national innovation system has been able to externalize some of its largely tacit indigenous knowledge and integrate this into the mainstream science and technology platform.

In order for Uganda to use science and technology as a platform for sustainability science research and sustainable development, it is necessary to identify the basic functions and capacities required. In this regard, the UNESCO project framework has shown the way forward by moving away from the traditional approach to the national innovation system, which has been in use for some years. Such a framework needs to address the pressing challenges of (i) access to clean and low unit cost energy; (ii) climate change mitigation, adaptation and resilience; (iii) food, nutrition and sustainable agriculture; (iv) access to quality health care for all at every age; (v) affordable shelter; (vi) employment generation; and (vii) wealth creation.

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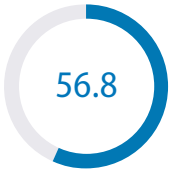
UGANDA
East Africa

OVERALL PERFORMANCE

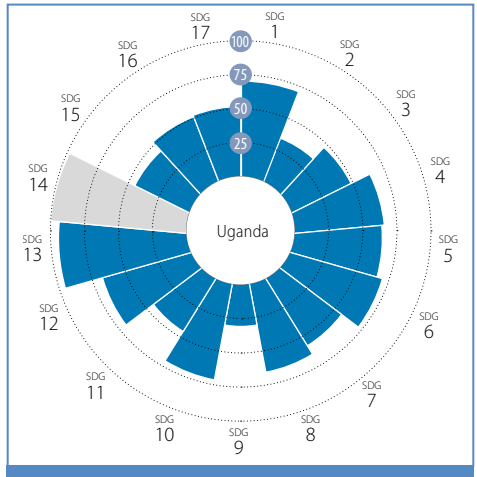
Index score



Regional average score

Africa Index Rank

13 (OF 51)



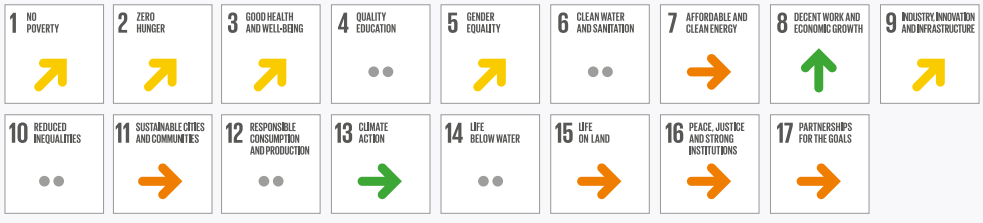
AVERAGE PERFORMANCE BY SDG

COMPARISON WITH OTHER AFRICAN INDICES

	RANK	SCORE
Africa Gender Equality Index (2015)	13 (of 52)	63.4 / 100
Africa Infrastructure Development Index (2016)	27 (of 54)	20.62 / 100
Africa Regional Integration Index (2016)	3 (of 52)	0.67 / 1
Ibrahim Index on African Governance (2017)	19 (of 54)	56.5 / 100

CURRENT ASSESSMENT – SDG DASHBOARD

SDG TRENDS



Notes: The full title of Goal 2 "Zero Hunger" is "End hunger, achieve food security and improved nutrition and promote sustainable agriculture".
The full title of each SDG is available here: https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals

Figure 7.6. Uganda Country Profile 2018.
The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

UGANDA
Performance by Indicator

SDG1 – End Poverty	Value	Rating	Trend
Poverty headcount ratio at $1.90/day (% population)	32.0	●	↗
Projected poverty headcount ratio at $1.90/day in 2030 (% population)	13.2	●	••
Proportion of population living below the national poverty line	19.5	●	••
Population covered by Social Protection (%)	75.7	●	••
SDG2 – Zero Hunger			
Prevalence of undernourishment (% population)	39.0	●	••
Prevalence of stunting (low height-for-age) in children under 5 years of age (%)	33.7	●	↗
Prevalence of wasting in children under 5 years of age (%)	4.8	●	↑
Prevalence of obesity, BMI ≥ 30 (% adult population)	5.3	●	→
Cereal yield (t/ha)	1.9	●	↓
Fertilizer consumption (kg per hectare of arable land)	2.4	●	→
SDG3 – Good Health and Well-Being			
Maternal mortality rate (per 100,000 live births)	343.0	●	↗
Births attended by skilled health personnel (%)	57.4	●	••
Neonatal mortality rate (per 1,000 live births)	21.4	●	↗
Mortality rate, under-5 (per 1,000 live births)	53.0	●	↑
HIV prevalence (per 1,000)	2.2	●	↑
People living with HIV receiving antiretroviral therapy (%)	67.0	●	••
Incidence of tuberculosis (per 100,000 people)	201.0	●	→
Proportion of children under 5 with fever who are treated with appropriate anti-malarial drugs (%)	64.5	●	••
Malaria mortality rate	29.1	●	↑
Coverage of Preventive Chemotherapy for Neglected Tropical Diseases (%)	53.1	●	••
Age-standardised death rate due to cardiovascular disease, cancer, diabetes, and chronic respiratory disease in populations age 30–70 years (per 100,000 population)	21.6	●	→
Traffic deaths rate (per 100,000 people)	27.3	●	→
Adolescent fertility rate (births per 1,000 women ages 15-19)	110.5	●	↗
Universal Health Coverage Tracer Index (0-100)	44.3	●	→
Age-standardised death rate attributable to household air pollution and ambient air pollution (per 100,000 population)	152.1	●	••
Percentage of surviving infants who received 2 WHO-recommended vaccines (%)	78.0	●	↑
Healthy Life Expectancy at birth (years)	62.3	●	↑
Subjective Wellbeing (average ladder score, 0-10)	4.0	●	→
SDG4 – Quality Education			
Net primary enrolment rate (%)	90.9	●	••
Mean years of schooling (years)	5.7	●	→
Literacy rate of 15-24 year olds, both sexes (%)	83.7	●	••
SDG5 – Gender Equality			
Proportion of women aged 20-24 years who were married or in a union before age 18	39.7	●	••
Proportion of girls and women aged 15-49 years who have undergone female genital mutilation/cutting, by age	1.4	●	••
Seats held by women in national parliaments (%)	34.3	●	↗
Women in ministerial positions (%)	36.7	●	••
Estimated demand for contraception that is unmet (% women married or in union, ages 15-49)	45.4	●	↗
Ratio of female to male mean years of schooling of population age 25 and above (%)	66.2	●	••
Ratio of female to male labour force participation rate	88.9	●	→
SDG6 – Clean Water and Sanitation			
Population using at least basic drinking water services (%)	NA	●	••
Population using at least basic sanitation services (%)	19.2	●	→
Freshwater withdrawal as % total renewable water resources	1.3	●	••
Imported groundwater depletion (m^3/year/capita)	2.4	●	••
SDG7 – Affordable and Clean Energy			
Access to electricity (% population)	20.4	●	→
Access to clean fuels & technology for cooking (% population)	2.0	●	→
Renewable energy share in the total final energy consumption	89.2	●	→
Consumer affordability of electricity	100.0	●	••

SDG8 – Decent Work and Economic Growth	Value	Rating	Trend
5-year average GDP growth per capita (%)	1.0	●	••
Employment-to-population ratio	83.2	●	→
Slavery score (0-100)	50.0	●	••
Adults (15 years and older) with an account at a bank or other financial institution or with a mobile-money-service provider (%)	59.2	●	↑
Starting a Business score	55.2	●	↑
SDG9 – Industry, Innovation and Infrastructure			
Infrastructure score (0-100)	35.4	●	••
Logistics performance index: Quality of trade and transport-related infrastructure (1=low to 5=high)	2.7	●	••
Research and development expenditure (% GDP)	0.5	●	••
Number of scientific and technical journal articles (per 1,000)	0.0	●	••
Mobile broadband subscriptions (per 100 inhabitants)	33.7	●	↗
Proportion of the population using the internet (%)	21.9	●	→
SDG10 – Reduced Inequalities			
Gini Coefficient adjusted for top income (1-100)	41.0	●	••
SDG11 – Sustainable Cities and Communities			
Proportion of urban population living in slums	53.6	●	••
Improved water source, piped (% urban population with access)	56.0	●	↓
Satisfaction with public transport (%)	43.0	●	↗
Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5) in urban areas (µg/m^3)	60.3	●	↓
SDG12 – Responsible Consumption and Production			
Municipal Solid Waste (kg/year/capita)	0.3	●	••
E-waste generated (kg/capita)	0.9	●	••
Natural Resource Value Realization Score	42.2	●	••
Production-based SO_2 emissions (kg/capita)	0.4	●	••
Anthropogenic wastewater that receives treatment (%)	0.4	●	••
Net imported SO_2 emissions (kg/capita)	0.2	●	••
SDG13 – Climate Action			
Climate Change Vulnerability Monitor (best 0-1 worst)	0.1	●	••
Energy-related CO_2 emissions per capita (tCO_2/capita)	0.1	●	→
Imported CO_2 emissions, technology-adjusted (tCO_2/capita)	0.2	●	••
CO_2 emissions embodied in fossil fuel exports (kg/capita)	0.0	●	••
SDG14 – Life Below Water			
Percentage of inadequately managed plastic waste	NA	●	••
Ocean Health Index Goal - Clean Waters (0-100)	NA	●	••
Ocean Health Index Goal - Biodiversity (0-100)	NA	●	••
Ocean Health Index Goal - Fisheries (0-100)	NA	●	••
Mean area that is protected in marine sites important to biodiversity (%)	NA	●	••
Percentage of Fish Stocks overexploited or collapsed by EEZ (%)	NA	●	••
Fish caught by trawling (%)	NA	●	••
SDG15 – Life on Land			
Mean area that is protected in terrestrial sites important to biodiversity (%)	73.7	●	→
Percentage change in forest area (2010-2015)	-3.4	●	••
Red List Index of species survival (0-1)	0.8	●	↓
Imported biodiversity threats (threats/capita)	0.4	●	••
SDG16 – Peace, Justice and Strong Institutions			
Homicides (per 100,000 people)	11.8	●	••
Conflict-related deaths per 100,000	0.0	●	→
Proportion of the population who feel safe walking alone at night in the city or area where they live (%)	59.0	●	↑
Children 5–14 years old involved in child labour (%)	16.3	●	••
Property Rights (0-100)	54.3	●	↓
Access to justice (0-100)	75.2	●	↓
Corruption Perception Index (0-100)	26	●	↓
Public Sector Accountability & Transparency (0-100)	38.1	●	↓
Birth registrations with civil authority, children under 5 years of age (%)	29.9	●	••
SDG17 – Partnerships for the Goals			
Tax revenue (% GDP)	14.1	●	→
Government Health and Education spending (% GDP)	9.4	●	••
Level of customs duties on imports	33.6	●	••
Visa Requirement score	37.0	●	••
Governmental Statistical Capacity	74.4	●	↓

Figure 7.7. Uganda performance by indicator.

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network.

References

AfDB. 2018. *African Economic Outlook 2018*. African Development Bank Group.

AUC. 2005. *The African Science and Technology Consolidated Plan of Action.* UNESCO, NEPAD http://www.nepadst.org/doclibrary/pdfs/doc27_082005.pdf http://www.unesco.org http://www.nepad.org

AUC. 2014. *Science, Technology and Innovation Strategy for Africa (STISA): On the Wings of Innovation*. Addis Ababa, African Union Commission.

AUC. 2015. *Agenda 2063: The Africa We Want. First Ten-Year Implementation Plan*. Addis Ababa, African Union Commission.

Branch, A. 2011. *Displacing Human Rights: War and Intervention in Northern Uganda*. Oxford, Oxford University Press.

Brar, S., Farley, S. E., Hawkins, R. and Wagner, C. S. 2010. *Science, Technology, and Innovation in Uganda: Recommendations for Policy and Action. A World Bank Study*. Washington DC, World Bank. http://documents.worldbank.org/curated/en/188271468115452838/Science-technology-and-innovation-in-Uganda-recommendations-for-policy-and-action

Bukenya-Ziraba, R., Doenges, P., Duez, P., Djoly, J. and Ogwal-Okeng, J. 1996. Medicinal plants sub-sector review: Pharmacopoeia promoting programme preparatory study. Draft of final report to the Ministry of Health. Archive of Ministry of Health, Uganda.

Churchill, W. S. 1910. *My African Journey*. London, Hodder and Stoughton.

CIA. 2018. *CIA World Fact Book 2017*. Updated January 20, 2018. New York, SkyHorse Publishing.

Daumerie, B. and Madsen, E. L. 2010. *The Effects of a Very Young Age Structure in Uganda. Country Case Study.* Washington DC, Population Action International, p.2.

Ecuru, J. 2013. *Unlocking Potentials of Innovation Systems in Low Resource Settings.* Karlskrona (Sweden), Blekinge Institute of Technology.

Ecuru, J. and Kawooya, D. 2015. Effective innovation policies for development: Uganda. *Global Innovation Index 2015*. Ithaca, Fontainebleau and Geneva, Cornell University, INSEAD and WIPO.

Ecuru, J., Trojer, L., Ziraba, Y. N. and Lating, P. O. 2012. Structure and dynamics of Uganda's technological innovation system. *African Journal of Science, Technology, Innovation and Development,* Vol. 4, pp. 255–74.

Ggoobi, R., Masekese-Wabukala, B. and Ntayl, J. 2017. *Economic Development and Industrial Policy in Uganda*. Kampala, Friedrich Ebert Stiftung.

Government of Uganda (GoU). 1997. *The Local Government (Amendments) Act 1997*. Entebbe, Government of Uganda.

GoU. 2001. *Uganda Forestry Policy*. Kampala, Ministry of Water, Lands and Environment, Government of Uganda.

GoU. 2007. *Uganda Vision 2040*. Kampala, National Planning Authority, Ministry of Finance, Planning and Economic Development, Government of Uganda.

GoU. 2009. *National Science, Technology and Innovation Policy for Uganda*. Kampala, Ministry of Science, Technology and Innovation, Government of Uganda.

GoU. 2010. *National Development Plan 2010/11–2014/15*. Kampala, Ministry of Finance Planning and Economic Development, Government of Uganda.

GoU. 2011. *Skilling Uganda, BTVET Strategic Plan 2011 - 2020*, Kampala, Ministry of Education and Sports.

GoU. 2012. *National Science, Technology and Innovation Plan*. Kampala, Ministry of Finance Planning and Economic Development, Government of Uganda, pp. 1–87.

GoU. 2013*a*. *National Forest Plan 2011/12–2021/22*. Kampala, Ministry of Water and Environment, Directorate of Environmental Affairs, Government of Uganda.

GoU. 2013*b*. *The Uganda National Land Policy*. Kampala, Government of Uganda.

GoU. 2016*a*. *Economic Impact of Refugee Settlements in Uganda*. World Food Programme and University of California.

GoU. 2016*b*. *Review Report on Uganda's Readiness for Implementation of the 2030 Agenda Theme: Ensuring that No One is Left Behind*. Kampala, National Planning Authority, Government of Uganda.

GoU. 2014. *Poverty Status Report 2014*. Kampala, Ministry of Finance Planning and Economic Development, Government of Uganda.

GoU. 2015*a*. *The Uganda National Land Policy Implementation Action Plan 2015/2016–2018/2019*. Kampala, Ministry of Lands, Housing and Urban Development, Government of Uganda.

GoU. 2015*b*. *Second National Development Plan 2015/16–2019/20*. Kampala, National Planning Authority, Government of Uganda.

Heng, Z., Filipiski, M., Valli, J., Gonzales, E., Gupta, A. and Taylor, E. 2017. *Economic Impact of Refugee Settlements in Uganda*. Dallas (US), Taylor Publishing House.

Hsu, A. (Dir.) 2016. *The 2016 Environmental Performance Index*. New Haven CT, Yale Center for Environmental Law & Policy. Available at: www.epi.yale.edu

IPC. 2012. *Food Security Phase Classification. Technical Manual V 2.0*. Rome, FAO.

IPC. 2017. *Uganda – Current Acute Food Insecurity Situation*. Technical Working Group, Integrated Food Security Phase Classification. www.ipcinfo.org

IPU. 2011. *Women in National Parliaments*. Inter-Parliamentary Union. Available at: www.ipu.org

Kasimbazi, E. and Alexander, K. 2011. *Environmental Law in Uganda*. Alphen aan den Rijn (Netherlands), Kluwer Law International.

Kazoora, C. 2002. *Road Map for Resource Mobilisation for the Implementation of National Action Program to Combat Desertification and Land Degradation in Uganda*. Ministry of Agriculture, Animal Industry and Fisheries, and Ministry of Finance, Planning and Economic Development. Kampala, Government of Uganda.

Klasen, S. and Lawson, D. 2007. *The Impact of Population Growth and Economic Growth and Poverty Reduction in Uganda*. Available at: https://www.researchgate.net/publication/5081419_The_Impact_of_Population_Growth_on_Economic_Growth_and_Poverty_Reduction_in_Uganda

Kruse, S.-E., Tedre, M., Kayobyo, G. 2014. *Evaluation of the Swedish Government Funded Research Cooperation Support to Uganda*. Sida Decentralised Evaluation, No. 39.

Markandya A., Cabot-Venton, C. and Beucher, O. 2015. *Economic Assessment of the Impacts of Climate Change in Uganda. Final Study Report*. Kampala, Climate Change Department, Ministry of Water and Environment, Government of Uganda.

Ministry of Education and Sports (MoES). 2013. *Ministerial Policy Statement 2012/13*. Kampala, Ministry of Education and Sports, Government of Uganda. Available at: http://www.education.go.ug/files/downloads/MPS FY 2012-13.pdf.

MoFED. 2009. *National Development Plan 2010/11–2014/15*. Kampala, Ministry of Finance, Planning and Economic Development.

NEMA. 2001. *Uganda State of the Environment Report 2000 Version 2*. Kampala, National Environment Management Authority, Ministry of Natural Resources, Government of Uganda.

NEMA. 2009. *Fourth National Report to the Convention on Biological Diversity*. Kampala, National Environment Management Authority, Ministry of Water and Environment, Government of Uganda, pp. 25–30.

NFA. 2017. *National Food Security Assessment Report*. Kampala, Department of Relief, Disaster Preparedness and Management, Office of the Prime Minister, Government of Uganda.

NRM. 2016. *National Resistance Movement Manifesto 2016–2021*. Available at: https://www.nrm.ug

OAU. 1985. *Declaration and Resolutions Adopted by the 21st Ordinary Session of the Assembly of Heads of State and Government*. Addis Ababa, Organization of African Unity.

OECD. 1989. *The Measurement of Scientific and Technical Activities: R&D Statistics and Output Measurement in the Higher Education Sector*. Paris, OECD.

OECD/Eurostat. 2005. *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*. 3rd Edition. OECD Publishing, Paris. https://doi.org/10.1787/9789264013100-en.

Olson, J. and Berry, L. 2003. *Land Degradation in Uganda: Its Extent and Impact*. Paper commissioned by the World Bank.

Pahl-Wostl, C., Gupta, J and Petry, D. 2008. Governance and the global water system: Towards a theoretical exploration. *Global Governance*, Vol. 14, No. 4, pp. 419–35.

Rwakakamba, T. M. 2009. How effective are Uganda's environmental policies? *Mountain Research and Development*, Vol. 29, No. 2, pp.121-27. http://www.bioone.org/doi/full/10.1659/mrd.1092

Silvia, A. 2014. Bulk of Uganda commercial oil production to start in 2017. *Reuters*, 9 May. Available at: http://www.reuters.com/article/2014/05/09/uganda-oilidUSL6N0NV4AW20140509.

Spangenberg J. H. 2011. Sustainability science: a review, an analysis and some empirical lessons. *Environ Conserv*, Vol. 38, pp. 275–87

Tabuti. J. and Van Damme, P. 2012. Review of indigenous knowledge in Uganda: Implications for its promotion. *Afrika Focus*, Volume 25, No. 1, pp. 29-38.

The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network (2018): Africa SDG Index and Dashboards Report 2018. Kigali and New York: The Sustainable Development Goals Center for Africa and Sustainable Development Solutions Network. Available at http://africasdgindex.org

UBS 2014*a*. *2014 Population Census.* Kampala, Uganda Bureau of Statistics, Government of Uganda.

UBS. 2014*b*. *Statistical abstract 2014*. Kampala, Uganda Bureau of Statistics, Government of Uganda.

UBS/ICF. 2017. *Uganda Demographic and Health Survey 2016: Key Indicators Report*. Kampala, Uganda Bureau of Statistics and the DHS Programme of ICF International.

UNBS. 2017. *Statistical abstract 2017*. Kampala, Uganda National Bureau of Standards, Government of Uganda. www.unbs.org (Accessed on 14 May 2018)

UNCST. 2012. *Statistical abstract*. Kampala, Uganda National Council for Science and Technology, Ministry of Finance, Planning and Economic Development, Government of Uganda.

UNCST. 2013. *National Survey of R&D 2012 Report*. Kampala, Ministry of Finance, Planning and Economic Development, Government of Uganda.

UNCST. 2017. *National Innovation Survey 2011–2014, Report 2016*. Kampala, Uganda National Council for Science and Technology, Ministry of Science, Technology and Innovation, Government of Uganda.

UNCTAD. 2011. *National Services Policy Review: Uganda*. Geneva, UN Conference on Trade and Development.

United Nations Development Programme (UNDP). 2012. *Gender Equality and Women's Empowerment in Public Administration: Uganda Case Study*. UNDP.

UNDP. 2014. *Uganda Evaluation of Country Programme Action Plan Outcomes (2010–2015)*. Evaluation report. Kampala, Delta Partnership Uganda Ltd.

UNDP. 2016. *Briefing note for countries on the 2016 Human Development Report*. New York, UNDP, p. 9.

UNDP. 2017. *Uganda's Contribution to Refugee Protection and Management*. New York, UNDP.

UNESCO. 2010. *UNESCO Country Programming Document, Uganda*. Paris, UNESCO.

UNESCO. 2015. *Mapping Research and Innovation in the Republic of Rwanda*. GO→SPIN Country Profiles in Science, Technology and Innovation Policy, Vol. 4. Paris, UNESCO

UNESCO. 2017. *Mobilization of National Capacities to Participate in Sustainability Science*. Paris, UNESCO. http://www.unesco.org/new/en/natural-sciences/science-technology/science-policy-and-society/science-policy-interface/future-earth/unesco-sida-future-earth-capacity-programme/

UNFPA. 2013. *Uganda MDG Report 2013.* Kampala, UNFPA.

UNFPA. 2015. *Responding to the Challenges of Poverty, Food Insecurity and Climate Change*. UNFPA.

UNHCR. 2015. *Uganda Energy and Environment Community Assessments*. UNHCR.

United Nations. 2010. *Science, Technology and Innovation for Sustainable Development in the Global Partnership for Development beyond 2015*. Thematic Think Piece. United Nations.

United Nations. 2017. *Concept note for Session 4 on National STI plans and policies for achieving the SDGs*. Multi-stakeholder Forum on Science, Technology and Innovation for the SDGs, 15–16 May. New York, UN.

World Bank. 2016*a*. *Uganda Poverty Assessment Report 2016. Farms, cities and good fortunes: assessing poverty reduction in Uganda from 2006-2013*. Report No. ACS18391. World Bank.

World Bank. 2016*b*. *Project Performance Assessment Report.* Uganda Millennium Science Initiative (IDA Credit no. 41740).

World Bank. 2017. *Country Poverty Brief, Sub-Saharan Africa, Uganda*. World Bank Group.

World Bank. 2018. *Closing the Potential-Performance Divide in Uganda Agriculture*. World Bank Group

WHO. 2017. *Uganda: MDG Goal 7: Ensure environmental sustainability - Other MDGs*. African Health Observatory/World Health Organization.

Witte, F., Goudswaard, P. C., Katunzi, E. F. B., Mkumbo, O. C., Seehausen, O. and Wanink, J. H. 1999. Lake Victoria's ecological changes and their relationships with riparian societies. H. Kawanabe, G. W. Coulter and A. C. Roosevelt (eds.), *Ancient Lakes: Their Cultural and Biological Diversity*. Ghent, Kenobi Productions.

Zake, J. S., Nkwijn, C. and Magunda, M. K. 1999. Uganda. H. Nabhan, A. M. Mashali and A. R. Mermut (eds), *Integrated Soil Management for Sustainable Agriculture and Food Security in Southern and East Africa: Proceedings of the Expert Consultation*. Harare, Zimbabwe, Food and Agriculture Organization of the United Nations.

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8

Conclusions: Towards sustainability science in Africa

8. Conclusions: Towards sustainability science in Africa

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8.1. Introduction

This book has examined the prospect of a sustainability science approach in five African countries – Ethiopia, Kenya, Rwanda, Tanzania and Uganda – through a set of studies and the results of extensive fieldwork. The studies are presented in Chapters 3 to 7, as well as a more global overview in the context of the African region, which is contained in Chapter 2.

The assessments were conducted through a pilot project funded by the Swedish International Development Agency (Sida) and implemented by UNESCO, the results of which could potentially lead to a comprehensive, continent-wide initiative aimed at mainstreaming the sustainability science approach in Africa. The main goal of this initiative would be to redirect current efforts in research and education towards co-design, and to transition to sustainable development pathways.

After analysing the country studies, the following question seems to remain: 'What does it entail to bridge the gap between the global discourse on sustainability science and sustainability science in practice, in the specific context of Africa, in the years to come?' (ICSU, 2005).

To address this question, this chapter draws on the lessons learned from the above-mentioned country studies and relevant field work conducted by UNESCO. It tries to establish a thread – if any – between the theory of sustainability science, its principles and guidelines for application, on the one hand, and the specific realities facing science and education in the countries studied, on the other.

Based on a comparative analysis of the findings in the studies as well as relevant field work, we can reflect on the need to contextualize global concepts and methodological approaches related to sustainability in the region. Thus, this chapter strives to analyse to what extent sustainability – while, in theory, a matter of societal choice (see, for example, Bendix et al., 2013) – is in practice the freedom of choice of individuals, and of society as a whole. Therefore, the chapter also seeks to assess the adequacy of governance and other framework responses in addressing the continent's multiple sustainability challenges.

The findings in the studies and their analyses are also considered against the background of general principles of sustainability science that have recently been formulated through a bottom-up, inclusive process facilitated by UNESCO (UNESCO, 2018*a*). In this concluding chapter, such principles are recalled, and the results of the comparative analysis are then presented according to thematic or cross-cutting clusters related to the application of sustainability science in the specific country.

The chapter also suggests possible future steps towards a transformative sustainability science agenda in the countries studied, drawn from the findings and elaborating upon the UNESCO *Guidelines on Sustainability Science in Research and Education* (UNESCO, 2018*a*) and the revised 1974 *Recommendation on Science and Scientific Researchers* (UNESCO, 2018*b*). It also presents related capacity development considerations and suggests how some of the current underlying causes of capacity barriers could be overcome. The chapter concludes with derived elements of a possible sustainability science vision in Africa.

8.2. The multiple and interlinked dimensions of sustainable development

Conflicts, poverty and hunger, weak education and health/sanitation systems, gender inequity, high population growth (as in Tanzania) and population density (in the case of Ethiopia and Uganda), all challenge sustainable development to a great extent, creating pressure on natural resources in countries that depend largely on agriculture and ecosystem services to feed and employ the majority of its rural (i.e. poorest and more marginalized) population. The interlinkages among the different pillars of sustainable development call for a holistic and integrated approach to understanding and informing actions, with a focus on the following areas:

8.2.1. Economic growth

All economic indicators over the past two decades show impressive sustained economic growth in Africa, including in the countries studied. In fact, seven of the ten countries with the highest growth rates worldwide are in Africa, including Ethiopia (average 10% growth) and Tanzania (average 7% growth). Further, it is expected that this growth will continue over the coming years, despite the current global economic slowdown observed in the past couple of years, particularly in China.

The observed growth in the countries studied, however, is concentrated in certain sectors of the African economy – which has the second highest global share based on natural capital and the lowest based on produced capital – and in specific geographical areas within the countries.

In fact, the continent's global importance in terms of biodiversity as well as the diversity in its peoples is recognized in several

studies. As the cradle of humankind, Africa is where human-environment interactions have the longest history (Diop, 1981; UNESCO, 2012) and where hundreds of millions of people still have a strong connection to nature and its multiple influences.

On the other hand, in most countries, the benefits of economic growth have not been broadly shared, as indicated by the low decrease of poverty rates, high food insecurity, youth unemployment and high GINI index, e.g. in Ethiopia and Tanzania. Despite this situation, the studies indicate an underlying trend of assimilating development with economic growth and economic growth with societal well-being. The country studies have shown that the impressive economic growth has not been translated into societal well-being or, in many instances, into environmentally sustainable solutions.

Political instability, institutional governance, corruption and low qualification/ opportunities for the largest youth population are among the causes. Only 17% of African youth (up to 35 years old) have stable jobs (AfDB, 2016) and, as stated in the Ugandan chapter of this book, this will be the most important single factor in determining the achievement of sustainable development goals (UNDP, 2017). According to the African Development Bank, 12 million young people entered Africa's labour force in 2015, but only 3.1 million jobs were created. That means that millions of young people were left without a share in the economy.

Agriculture is still the basis for Africa's growth – it is the largest economic sector, representing 15% of the continent's total GDP, or more than US$100 billion annually. The sector has also a pivotal role in employment in sub-Saharan Africa, providing wok for more than half of the total workforce; it is also the primary source of livelihood for 10–25% of urban households (OECD-FAO, 2016).

Despite its importance, the sector has seen investment decrease in agricultural R&D during the last decades, and only a few countries have reached the annual 10% of the national budget agreed in the Maputo Declaration (AUC, 2003). However, the continent suffers the highest and fastest-growing rate of acute food insecurity on the planet: 29.8% (FSIN, 2018). The lack of appropriate funding challenges the concept that R&D investment returns in terms of poverty reduction are often not only stronger but also steadier than that of other types of agricultural public spending (Mogues et al., 2012).

The informal economy is a dominant sector in Africa, as it is in other developing regions of the world. Various studies suggest that the informal economy in sub-Saharan Africa remains among the largest in the world, although this share has been very gradually declining. According to ILO (2018), the informal sector is a huge employer in Africa, representing about two-thirds of non-agricultural employment and around 79% of total employment in sub-Saharan Africa. About 93% of new jobs created in Africa during that 1990s were in the informal economy.

Photo 8.1. Telephone recharge kiosk covering all teleoperators in Mombasa (Kenya).
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It is also clear from the studies that informality has a notable influence on sustainability and on achieving the SDGs. One of many examples is that of public transport: SDG 11 calls for more sustainable public transport systems, which are needed in many African cites. However, the introduction of formal mass public transport systems necessitates complex, often fraught, trade-offs with informal sector transport service providers. Failure to adaptively manage the complexity of this transition in the transport sector has resulted in violent protests and the destruction of infrastructure in some African countries (UNESCO, 2016).

Therefore, a better understanding of the relationship between formal and informal systems is needed to enhance the co-production of transdisciplinary knowledge and to inform economic and social policy decisions, especially those benefiting the most vulnerable sectors of the population (including youth and women in rural areas).

The need for a better assessment of the informal sector is equally relevant when referring to its impact and contribution to the science, technology and innovation (STI) system. The STI Strategy for Africa 2024 (STISA) and the African Observatory of STI have adopted the OECD manuals based on the National Innovation Systems concept,[1] with limited attempts to propose indicators adapted to the specific needs of the region, e.g. the measurement of innovation in the informal sector.

The issue of measuring the informal economy is also key in the discussions related to GDP-based indicators. The Multiple Indicator-Multiple Causes method (Tekwe et al., 2014) is a well-established tool for measuring informal economic activity. However, it has been criticized because GDP is used both as a cause and indicator variable. To address this issue, the paper by Medina et al. (2017) applies the light intensity approach for the first time (instead of GDP). It also uses the Predictive Mean Matching (PMM) method to estimate the size of the informal economy for sub-Saharan African countries over 24 years.

In 2011, UNESCO launched the Science, Technology and Innovation Global Assessment Programme (STIGAP), gathering experts to reflect on more integrated models and measurement gaps, especially in developing countries, to promote STI policies that contribute to building peace, inclusive societies and sustainability. The programme is now part of the UNESCO Global Observatory of STI (GO→SPIN) and is included in the reflections towards the preparation of a future Paris Manual that will act as a standard-setting instrument within GO→SPIN and recommend standard practice for surveys on STI policy instruments, as well as on STI governing bodies and policies.

8.2.2. Poverty and inequality: Main barriers for sustainable development

All country studies identify poverty as a hindrance to sustainable development. Poverty indicators show the enormous challenges faced by the five countries in order to overcome this social ill in the medium- or even long-term. This is relevant to the whole continent, where poverty has not fallen as much, or as quickly, as expected and economic inequalities remain the major barrier to sustainable development.

Africa is the second most unequal region in the world after Latin America and, if left unchecked, this inequality could jeopardize the sustainability of economies, societies and communities (UNESCO, 2016). It is a powerful barrier to the general Agenda 2030 principle of 'no one will be left behind' and specifically to SDGs 10 and 5, which are directed at reducing inequalities within and among countries and on gender (**Figure 8.1**).

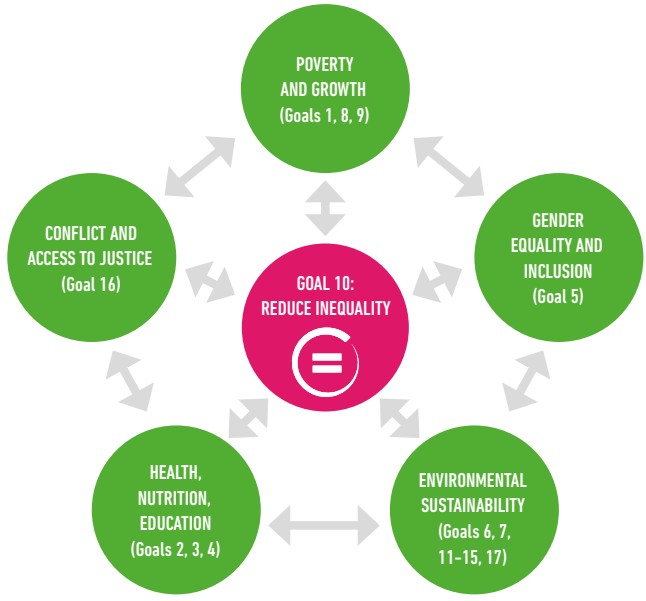

Figure 8.1. Interrelation of SDGs related to the reduction of inequality.
Source: UNESCO, 2016.

Inequality is present in many interrelated forms. Children from low-income families and other marginalized groups, especially those living in rural areas, often have less access to quality education than others; later, their inequality in learning achievement leads to inequality in employment and earnings. This illustrates the vicious circle of inequality and the mechanisms of its reproduction. In the same way, socio-economic inequalities interact with political inequality in terms of voice, representation and influence, so that those most affected by inequality often have the least power to respond to and change their situation.

Youth, especially from rural areas, are particularly impacted by inequalities with low access to education, knowledge, decent jobs and decision-making processes. The average age of an African president is 62 while the median age of Africa's population is 19.5, representing the world's largest age gap and influencing the poor understanding of the needs of young people among policy-makers (UNDP, 2017).

Yet, the findings in the country studies tend to refer to poverty and inequality-related issues as depending on governance and institutional issues more than as an underlying driver of unsustainability per se. While these issues certainly impinge on inequality, it is no less true that more co-production of knowledge is necessary to address social ills, such as the high

1 OECD Oslo Manual

rates of poverty and inequality and the risk of their increase in view of population growth and climate change vulnerability in the region, which also place extra pressure on resources.

Reducing inequality in sub-Saharan Africa would require an urgent strengthening of the science-policy-society nexus, as researchers are neither sufficiently addressing the knowledge gap from an interdisciplinary and integrated manner, nor properly advising policy-making.

This research gap is in line with the African research community's interest in poverty, gender equality and climate change (Chapter 2) and the faster average annual growth in studies on inequality. However, the sharp decline in poverty studies and low level of research on the contribution of the informal sector to poverty/inequality reduction indicate the need for a better science-policy-society interface to drive a programme of inclusive development, active social policy (combining redistribution and growth in productive capacity) and tackle the norms and practices that sustain discrimination and promote the integration of societal actors and researchers in policy formulation.

In the policy advisory role of sustainability science, the need for better metrics for sustainable development is particularly important, as will be discussed in the following section, in relation to education and health. These are key barriers for stability and sustainable development in Africa, to which sustainability science can reply by building evidence towards a comprehensive policy agenda, comprising demographically informed measures that address political, cultural and economic exclusion in a synchronized manner.

8.2.3. Education and health

Poor and unequal access to, and completion of, formal education, and the clear relation between wealth level and gender, seem to indicate that the conditions for investing in science education as a lever for sustainable development in any country are largely unmet.

Of all regions in the world, sub-Saharan Africa has the highest rates of education exclusion. According to UIS data, almost 60% of youth between the ages of around 15–17 are not in school.[2] Without urgent action, it is clear that the situation is likely to worsen, as the region faces a rising demand for education due to a growing school-age population.

Girls' education is a major priority, according to UIS data. Their disadvantage starts early: 23% of girls are out of primary school compared to 19% of boys. By the time they become adolescents, the exclusion rate for girls is 36%, compared to 32% for boys.

The Borgen Project (2017) gives 10 facts about education in Africa:

1. Africa has the highest rates of educational exclusion in the world. Over one-fifth of children between the ages of 6 and 11 and one-third between the ages of 12 and 14 are out of school.
2. Almost 60% of children in sub-Saharan Africa between the ages of 15 and 17 are not in school.
3. Girls are much more likely to stay out of school than boys. Nine million girls between the ages of around 6 and 11 in Africa will never go to school at all, compared to six million boys.
4. The number of primary-aged children not attending school in Africa accounted for more than half of the global total.
5. Mom Connect, an SMS texting programme based in South Africa, provides educational information regarding health care and health insurance coverage. The platform connects female health workers with other women who may have health questions or concerns about their families. Apps such as this one provides knowledge where gaps exist in the educational system.
6. In sub-Saharan Africa, only about one-quarter of pre-primary teachers are trained. Upper secondary school teachers have a slightly better ratio: about 50% benefit from training.
7. UNICEF partnered with the LEGO Foundation to establish an online training platform that reached 150,000 teachers in South Africa in 2016 alone.
8. The rate of gross enrolment in tertiary education in sub-Saharan Africa is the lowest in the world, standing at only 8% as of 2014. This is far lower than the gross enrolment of the second lowest region, Southern Asia, which is at 23%, whereas the global average is 34%.
9. Sub-Saharan Africa is in direct contrast with Eastern Europe and Central Asia when it comes to gender disparity in education within urban areas. The latter tend to see a higher level of both educational attainment and literacy among females, while sub-Saharan Africa sees the opposite.
10. If every girl in sub-Saharan Africa completed even just a primary education, the maternal mortality rate would likely decrease by 70%.

2 UNESCO Institute of Statistics data base

On the other hand, health and the standard of living may hamper the different countries from benefiting from a development benchmark supporting the ambitious goal of the stated national visions for the future of passing to the next level of economic development.

Photo 8.2. Girls school visiting Parc Haller reserve, Mombasa (Kenya).
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A report by WHO (2014) provides a comprehensive analysis of key public health issues and progress made in the Africa region. These issues have been reported as follows:

1. HIV/AIDS continues to devastate the WHO Africa region, which has 11% of the world's population but 60% of the people with HIV/AIDS. Although HIV/AIDS remains the leading cause of death for adults, more and more people are receiving life-saving treatment. The number of HIV-positive people on antiretroviral medicines increased eight-fold, from 100,000 in December 2003 to 810,000 in December 2005.
2. More than 90% of the estimated 300–500 million malaria cases that occur worldwide every year are African, mainly in children under five years of age, but most countries are moving towards better treatment policies. Of the 42 malaria-endemic countries in the Africa Region, 33 have adopted artemisinin-based combination therapy – the most effective antimalarial medicine available today – as a frontline treatment.
3. River blindness has been eliminated as a public health problem, and guinea worm control efforts have resulted in a 97% reduction in cases since 1986. Leprosy is close to elimination – meaning there is less than one case per 10,000 people in the region.
4. Most countries are making good progress on preventable childhood diseases. Polio is close to eradication, and 37 countries are reaching 60% or more of their children with measles immunization. Overall, measles deaths have declined by more than 50% since 1999. In 2005 alone, 75 million children received measles vaccines.

The WHO report stresses that Africa will only be able to move forward on recent progress by strengthening its fragile health systems.

8.2.4. Gender issues are largely uncharted

Women have multiple identities as members of excluded groups. Growing up in an increasingly unequal world has enormous consequences for children, both girls and boys, for their education, employment and nutrition, and for their aspirations and identities. Such intersecting inequalities contribute to a lack of material well-being, and have further psychological and intangible consequences, not only for those at the bottom of the inequality ladder, but for the middle classes as well (UNESCO, 2016).

The UNESCO *Recommendation on Science and Scientific Researchers* (UNESCO, 2018*b*) states that 'Member States should ensure that initial education and training of scientific researchers is provided without discrimination based on … gender. Performance appraisal systems about scientific researchers in their employ should be … gender-sensitive. As part of the conditions for success on the part of scientific researchers, Member States should ensure that scientific researchers enjoy equitable conditions of work, recruitment and promotion, appraisal, training and pay without discrimination based on … gender'.

Achieving the gender equality and inclusion goals of the SDGs will perhaps be the most challenging target of all. Multiple inequalities (economic, political, social, cultural, environmental, spatial and knowledge-based) not only intersect, but also accumulate and affect some groups more than others.

Several studies show that women and girls have multiple identities as members of excluded groups in Africa. In the country studies, the Ethiopian chapter refers to cultural causes of gender-based differences. In Rwanda, gender-specific solutions seem to have been identified or piloted, such as the development of minimarkets for female hawkers in Kigali City. The Kenyan chapter also recognizes the question of gender

inequality as central to the application of the sustainability approach, without providing a specific explanation as to what may be hampering gender quality and why this represents a significant contribution to the achievement of sustainability.

However, as indicated earlier, Chapter 2 shows that SDG linkages among gender and other inequalities (SDGs 5 and 10) receives little attention in both literature and policy documents in Africa; these linkages should be studied and be promoted to raise awareness and to inform policies that are key for the region's sustainability.

The gender dimension of sustainability science tackles two different but interrelated issues: the role of women in society and their contribution to sustainability solutions; and the role of women in science and consideration of gender demands in the research agenda. Both dimensions have not been fully tackled in studies conducted thus far, despite their critical importance to crafting appropriate policy for mainstreaming sustainability science in research and education in the countries studied in this book, and in Africa as a whole.

8.2.5. Conflicts, climate change and hunger

Conflicts and climate change shocks are challenging the attainment of SDG 2 (Zero hunger) in the Africa region, where the percentage of acute food insecurity[3] is the highest by far: 29.8% of the region's population, followed by the Latin American region with 9.8% in 2017, according to the latest global report on food crisis (FSIN, 2018). More worrying still is the fact that this percentage has been increasing over recent years from the 2014 figure of 22.3%.

Conflict continues to be the main driver of acute food insecurity in 18 countries – 15 of them in Africa or the Middle East. Sub-Saharan Africa hosts more than 26% of the world's refugee population. Conflict is also the primary reason for most of the world's cases of acute food insecurity, accounting for 60% of the global total, or 74 million people.

Climate disasters – mainly drought – were also major triggers of food crises in 23 countries, two-thirds of them in Africa, and were responsible for pushing some 32 million people into acute food insecurity, with children and pregnant/breastfeeding women the most vulnerable. Drought in East Africa damaged already strained livelihoods, destroyed crops and pushed up food prices, particularly in Ethiopia, Somalia and Kenya. Southern Africa suffered severe food insecurity conditions in early 2017, following a prolonged drought in 2015/16. Western African and Sahel countries, including Burkina Faso, Chad, Mali, Mauritania, Niger and Senegal, are also expected to face increased food insecurity in pastoral areas, due to the lingering effects of dry weather in 2017.

Climate change increases the number and impact of events related to climate variability. In the Eastern Africa region, changes in the climate regime have caused an epidemic of a viral cattle disease, Rift valley fever. In the case of Kenya, this epidemic caused the death of more than 420,000 bovines and losses in milk benefits were estimated at more than 2.5 million l in 2006 and 2007 alone, with direct impacts on the food security and nutrition conditions of the northern populations (FSIN, 2018).

The combination of climate shocks and conflict displacement causes a sustainability crisis. Ethiopia counts 8.5 million food-insecure people in need of urgent action (FSIN, 2018) and 40% of children are stunted. Furthermore, food insecurity is becoming more severe due to the prolonged impact of el Niño-induced drought, political instability, armed clashes and population displacement (1.7 million internally displaced due to poor rains and almost 900,000 refugees from neighbouring countries).

Photo 8.3. Child in Gambo (Ethiopia). Child food insecurity and inequalities are enhanced in rural areas due to climate change.
© UNESCO/J. Chaves-Chaparro

The lack of rain in 2016 in Uganda led to increased food insecurity in early 2017, at a time when the country was already facing high food insecurity due to an influx of refugees, mainly from South Sudan, and with a total of 1.4 million refugees in the country. Since then, Uganda has hosted the largest refugee settlement in the world – Bidi Bidi – housing over 270,000 South Sudanese refugees with high social and environmental challenges.

3 Acute food insecurity is when a person's inability to consume adequate food puts their lives or livelihoods in immediate danger. It is a metric that draws on internationally-accepted measures of extreme hunger, such as the Integrated Food Security Phase Classification (IPC) and Cadre Harmonisé (CH), and is equivalent to IPC scale 3 levels of hunger and worse (IPC 3 - crisis; IPC 4 - emergency; IPC 5 - famine/catastrophe). Level 5 is the most extreme symptom of acute and protracted crises.

8.3. An integrated approach to environmental challenges

The Ethiopian chapter reminds us of the very definition of sustainable development: 'Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Sustainable Development, 1987).

While the environmental dimension of sustainable development is probably the most intuitively justifiable from the perspective of a systems approach in the provision of services central to human well-being, integrating the social and economic dimensions of development with the environmental component poses several challenges.

The UNESCO-Sida consultation workshops underpinning several of the findings in this publication, which included key national stakeholders, concluded that actionable knowledge and innovation covering the nexus between water, food and energy was a priority for the five countries studied, all of which are especially affected by the high climate change vulnerability of the region. This is in line with the indications in Chapter 2 of sub-Saharan Africa's high dependency on surface water for drinking and energy; 26% of the world population with only 25% access to electricity.

The authors of Chapter 3 refer to conflicts between nature, people and economics. They stress the role of research and innovation as drivers of sustainable development, but hand in hand with cooperation and governance. They advocate that it is the balance in the relationship between research and innovation and governance, as well as the synergistic nature of their relationship, that can reduce social tensions and provide opportunities for economic and environmental sustainability.

The Ethiopian chapter illustrates a clear link between traditional agricultural practices, demands for land, impacts on biodiversity and climate change. Integrated strategies, such as production of energy from waste, constitute a response to the demand of specific sectors – energy, in this case. But the review about Ethiopia's environmental sustainability undertaken in the chapter has the benefit of examining the availability of resources from a much broader perspective: access to those resources, health, competition and conflicts between traditional and modern uses of the resources, and climate change.

In essence, the 'environmental' dimension of sustainability constitutes a reductionist and simplistic view of more complex problems: the alteration of the quality and quantity of the benefits of nature is not a mere reflection of extractive practices, climate change or species introduction and removal; rather, the loss of ecosystem services is the result of underlying factors of change (mostly of a social and cultural nature), such as demographics, governance, ethnic tensions, institutional and legal frameworks, science and technology, and unsustainable use practices. Some of these drivers are quite remote from the local environmental problem in question, such as globalization, trade, market and policy frameworks (Millennium Ecosystem Assessment, 2005; Diaz et al., 2015).

In the case of Tanzania, and the devolved competencies of the Zanzibar archipelago, the need for an integrated and interdisciplinary approach to the environmental dimension of sustainable development is institutionalized under the Ministry of Lands, Water, Energy and Environment of Zanzibar.

In the case of Rwanda, the country is aware of its environmental sustainability challenges. Issues posed by fast-growing urbanization, clearance of critical ecosystems and inequalities are viewed through an integrated window combining societal needs with the need to ensure proper scientific knowledge to effect the desired transformation.

Rwanda's national strategy for green growth and climate resilience reflects a sustainability science approach at the core of its design. Working alongside the knowledge action network on decarbonized societies pursued by Future Earth (Wilson, 2017), Rwanda has not only developed a sound green growth framework but also complemented it with a specially dedicated fund. This approach has been successfully tested through a pilot project on Operationalizing Green Economy Transition in Africa under the UN Environment Programme and GIZ-Germany.

Science in Africa needs to better address the relationship between conflicts, economy, hunger, health, migration and climate change, among others. Therefore, the adoption of the holistic approach of sustainability science could make a difference in the region and support the design of urgent structural measures that tackle the different aspects of the sustainable development agenda in Africa.

8.4. The measurement of sustainable development

8.4.1. The issue of indicators

There is a growing consensus in the scientific and policy community, as stated in the *2009 Report from the Commission*

on the Measurement of Economic Performance and Social Progress (Stiglitz et al., 2009), on the need to improve the way we measure and monitor progress aligned to the concept and practice of sustainable development, from a production-oriented measurement system towards one focused on the well-being of current and future generations in a context of sustainability. The purpose of such a measurement system is to have a set of indicators that give an 'alert' to situations that pose a high risk of non-sustainability, and thus increase knowledge on how the economy and the environment interact now and are likely to interact in the future.

Of special relevance to the African context, the Commission stated that if inequality increases enough relative to the increase in average per capita GDP, most people could be worse off, even though average income is increasing. When associated with global warming, market prices are distorted by the fact that there is no charge imposed on carbon emissions, and no account is made of the cost of these emissions in standard national income accounts. Clearly, measures of economic performance that reflect these environmental costs might look markedly different from standard measures.

In the context of the SDGs, a large number of attempts to quantify sustainability have been considered. The report *Review of Targets for the Sustainable Development Goals: The Science Perspective* (ICSU-ISSC, 2015) proposes an overarching goal – 'a prosperous, high quality life that is equitably shared and sustainable' – and highlights the need for new integrated economic metrics of progress beyond GDP, the Human Development Index and other established aggregate indices which were already reviewed in the UN's *Prototype Global Sustainable Development Report 2014*.

Under the leadership of the United Nations, 232 official SDG indicators have been agreed upon. While progress is being made in collecting data for these indicators, data are lacking for many official metrics in most countries, particularly across Africa. According to a recent analysis of the data availability for the SDGs, only 37.8% of official SDG indicators have data for African countries (UNECA, 2017).

The above context urges a return to the fundamental questions for African researchers and policy-makers: What do we want to measure? How can important sustainability elements in developing countries, and in Africa in particular, be integrated? How can we provide clear policy advice and build the necessary capacity in the Africa region to contribute effectively to this process?

Photo 8.4. Consumers in African countries are affected the most by high food prices, due to the high percentage of their income that they spend on food. Local primary food market prices are very much affected by global economy and climate change in the poorly market-protected African economies.
© UNESCO/J. Chaves-Chaparro

The SDG Centre for Africa and the plans for the creation of an African Economic Commission in 2028 will be a timely opportunity to broaden this discussion and develop regional statistical capacity. At present, African statistical offices are generally low in the World Bank ranking of statistical capacities (World Bank, 2017).

The Agenda 2063 (AUC, 2015) has 20 goals with 174 targets, while there are 17 SDGs with 169 corresponding targets. These goals broadly converge on social and human capital development, inclusive economic growth, peaceful societies, accountable institutions, and environmental sustainability dimensions. However, there are topics of divergence as well. Crucially, these agendas are operating in very different time frames: only 15 years for the SDGs, as opposed to 50 for the Agenda 2063. As such, comparison of the varying quantitative targets is not straightforward. Themes such as inequality (between and within nations), sustainable management of land ecosystems (desertification, biodiversity and land degradation), responsible consumption and production and urgent climate action are central to the SDGs but are not as fully developed in Agenda 2063.

Conversely, Agenda 2063 has a strong identity component, emphasizing that the structural transformation needs to be endogenous, integrating the continent and raising the profile of African culture, values and heritage. It also fosters domestic resource mobilization (but also including regional and continental targets) and has flagship projects focusing on transport, information and communication technologies (ICT), and energy infrastructure.

8.4.2. Achieving the Sustainable Development Goals

The *Africa SDG Index and Dashboards Report 2018* (SDG Centre for Africa and SDSN, 2018) recognizes that Africa faces substantial challenges in achieving the SDGs. **Figure 8.2.** shows the 2018 Africa SDG Dashboards measuring the countries' current progress towards achieving the SDGs. The greatest challenges are found in health (SDG 3), infrastructure (SDG 9) and peace in strong institutions (SDG 16), with more than 80% of countries scoring red in the Dashboard coloring system. At the same time 70% of the countries also score red in the SDG of food security and sustainable agriculture (SDG 2), energy access (SDG 7) and marine ecosystems (SDG 14). For 14 of the 17 goals, not a single African country has achieved green status.

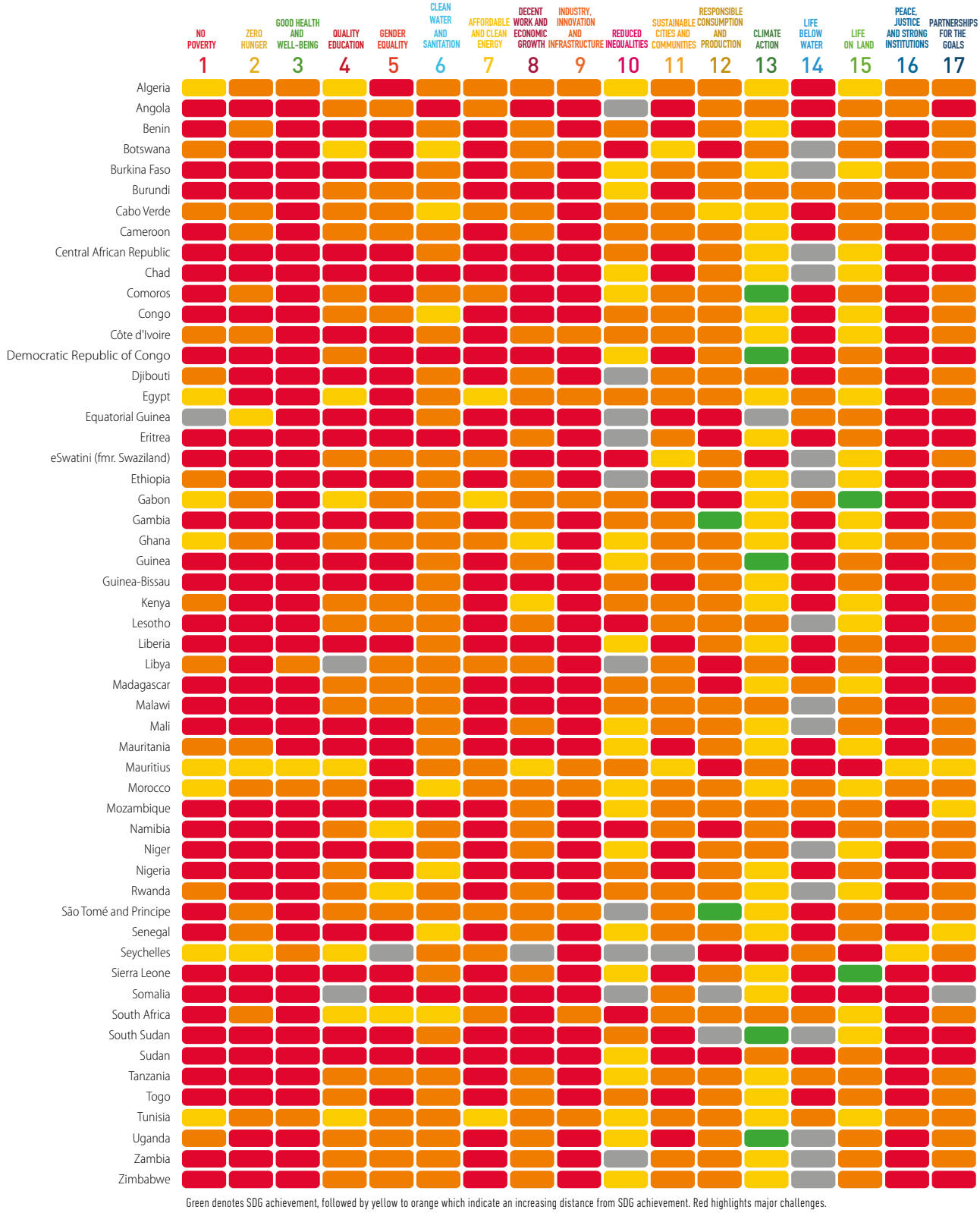
In the case of the remaining three goals, there are only a handful of green countries – climate action (SDG 13) has five greens, and terrestrial ecosystems (SDG 15) and sustainable consumption and production (SDG 12) have three and two greens, respectively. These dashboards indicators are not necessarily attributed however to the countries' achievements but rather to their socio-economic levels, as poverty is central to all other SDGs (ICSU, 2015) and the fact that Africa is the poorest region in the world, with sub-Saharan African accountable for half of the world's extreme poverty.

Other challenges to achieve SDGs come from the existing large knowledge and digital gaps that limite the participation of scientists from developing countries to participate in decisions about global science agendas, and further, bilateral donors and institutions often exert a strong influence on the policy choices of developing countries, including those regarding STI systems (UNESCO, 2016).

Regional disparities in the production of publications on inequalities and social justice are also very high – nearly half of all SHS publications (49.3%) on the theme of inequality and social justice between 1992 and 2013 were produced in the developed world, while sub-Saharan Africa only accounts for 3.2% of the total, together with Latin America and East and Southern Europe that also lag in publications despite being the more unequal regions worldwide. In this regard, UNESCO's *World Social Science Report 2016* highlighted the need to produce more interdisciplinary, multiscale and globally inclusive research agendas to inform pathways toward greater equality, opening a very timely window for sustainability science research.

The results discussed in Chapter 2 show that linkages between gender and other inequalities (SDGs 5 and 10) have benefited from little attention in both literature and policy documents in Africa and should be promoted to raise awareness and inform policies that are key for the region's sustainability. The same applies to the study of the relationships between inequalities and corruption (SDGs 5 and 16).

There are also other interesting opportunities and challenges that are brought forward in the previous chapters regarding the attainment of SDG 8, in relation to the need to create employment and decent work, especially for youth. The employment issue should be of great concern today, especially with the advances of new technologies. This is an issue that is not explicitly discussed in any of the country studies, but which is put forward here by way of a policy recommendation.



Green denotes SDG achievement, followed by yellow to orange which indicate an increasing distance from SDG achievement. Red highlights major challenges.

Figure 8.2. Africa Sustainable Development Goals Dashboard.

Source: SDGC/A and SDSN 2018, SDG African Index (page 18).

Figure 8.3 below shows the number of links through SDG targets, as suggested by the scientific literature.

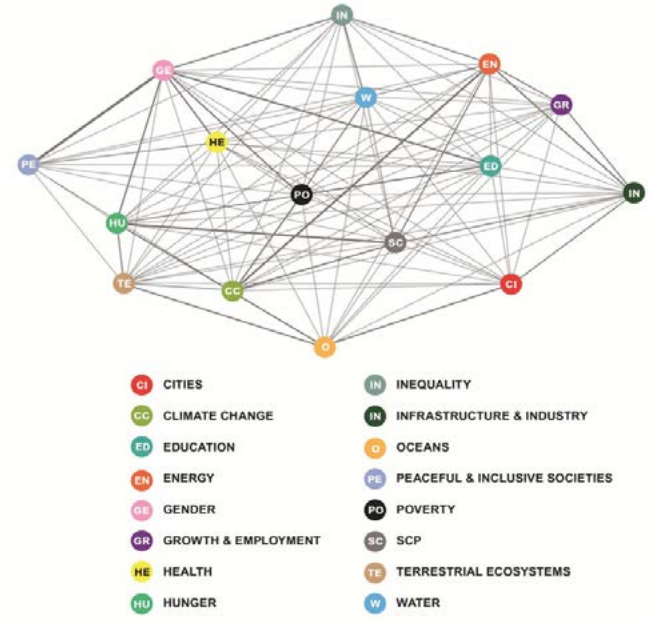


Figure 8.3. Linkages among SDGs.
Source: ICSU-ISSC, 2015.

8.5. UNESCO's principles of sustainability science: A recollection

In the period between 2010 and 2014, consultations among Member States of UNESCO led to the identification of sustainability science as one of the strategic objectives to help the Organization deliver in relation to its overarching objectives, and to achieve sustainability and adaptation to global and climate change, through the pursuit of natural and social sciences, and through education (Aricò, 2014; Kauffmann and Aricò, 2014; UNESCO, 2014).

According to the UNESCO *Guidelines on Sustainability Science in Research and Education* (UNESCO, 2018*a*), the following principles should apply throughout the whole process for conceiving and monitoring interventions based on the sustainability science approach:[4]

a) Sustainability science is an interdisciplinary domain of research and education that reflects the complexity of interactions of natural, social and cultural sustainability challenges that take place at multiple geographical and temporal scales. The global and local sustainability challenges imply many conflicts of goals and interests, with the need for balance and compromise.

b) The application of knowledge generated through research in sustainability science aims to respond to such sustainability challenges and largely relies on new technologies and innovative processes.

c) By generating actionable knowledge and solving problems, sustainability science contributes to reducing conflicts by promoting integrated policy agendas at multiple scales.

d) In addition to its multidisciplinary nature, sustainability science represents a multistakeholder endeavour, aimed at the co-design of research, co-production of knowledge and co-management of the application of the knowledge generated.

e) Sustainability science entails academic freedom and responsibility towards societal needs.

f) Sustainability science requires a new generation of scientists reflecting combined established skills, such as critical analysis, systems thinking and uncertainty, combined with the capacity to recognize diverse values, conflicts of goals and interests, as well as the need to strengthen such new combined capacities through all forms of education.

While the case studies presented in this book generally follow the above, it is worth considering to what extent the principles of sustainability studies are operationalized in the light of specific challenges being faced by the countries studied, and the role of science therein, with some generalizations that might embrace the whole of Africa.

The operationalization of sustainability science requires adequate scientific institutions, specific framework conditions and the provision of targeted resources from education and STI policies. Responding to this requirement, and as part of its mandate, UNESCO adopted in 2017 (UNESCO, 2018*b*) the *Recommendations on Science and Scientific Researchers*, which supersedes the 1974 publication *Recommendation on the Status of Scientific Researchers*, in line with new global challenges and agreements, towards the SDGs and the Paris Agreement. Some of the more relevant recommendations in relation to the sustainability science principles and drivers, especially in relation to the role of researchers and policy-makers in its implementation, are given below.

4 Paraphrased by the authors of this chapter from the original text in the UNESCO Guidelines which describes the principles of sustainability science.

In line with the 'Sustainability Science principles', Article 16 on the *civic and ethical aspect of scientific research* recommends that: 'Member States should encourage conditions that can deliver high-quality science in a responsible manner…'. For this purpose, Member States should establish mechanisms and take all appropriate measures aimed to ensure the fullest exercise, respect, protection and promotion of the rights and responsibilities of scientific researchers and others concerned by this recommendation.

For the above purpose, the following are some of the key recommended responsibilities and rights of scientific researchers:

a) To work in a spirit of intellectual freedom to pursue, expound and defend the scientific truth as they see it, an intellectual freedom which should include protection from undue influences on their independent judgement.

b) To contribute to the definition of the aims and objectives of the programmes in which they are engaged and to the determination of the methods to be adopted which should be humanely, scientifically, socially and ecologically responsible; researchers should seek to minimize impacts on living subjects of research and on the natural environment and should be aware of the need to manage resources efficiently and sustainably.

c) To express themselves freely and openly on the ethical, human, scientific, social or ecological value of certain projects, and in those instances where the development of science and technology undermines human welfare, dignity and human rights or is 'dual use', they have the right to withdraw from those projects if their conscience so dictates and the right and responsibility to express themselves freely on and to report these concerns.

d) To contribute constructively to the fabric of science, culture and education, and the promotion of science and innovation in their own country, as well as to the achievement of national goals, the enhancement of their fellow citizens' well-being, the protection of the environment, and the furtherance of international ideals and objectives.

e) To ensure that knowledge derived from sources, including traditional, indigenous, local and other knowledge sources, is appropriately credited, acknowledged and compensated, as well as to ensure that the resulting knowledge is transferred back to those sources.

8.6. Specificities of sustainability science in Africa

Ethiopia, Kenya, Tanzania and Uganda represent four out of the five African research hubs for sustainability science (Elsevier, 2015), the fifth being South Africa,[5] whose STI system is quite unique in the region and does not provide a representative case of the whole continent for comparative purposes. Therefore, the analysis of the four national STI systems and their contribution to sustainable development agendas can provide a good overview of the best practices in the continent.

Moreover, Rwanda, in view of the strong national policy framework towards sustainability and its leadership in subregional scientific cooperation on SDGs, would appear to be a good case study in terms of comparing and offering policy advice to the rest of the country, and becoming the continent's research hub for sustainability science.

The analysis and comparison of the findings in the previous chapters has led to the identification of a set of elements related to sustainability and sustainability science, as presented and discussed in the next section. These elements are introduced purely for illustrative purposes, in order to analyse the different ways in which African countries have dealt with, for example, environmental issues and the possible contribution of sustainability science to their resolution. The sets of elements are not intended to represent a rigid grid to analyse the application of sustainability science in the countries studied or in Africa, rather a merely analytical tool leading to the subsequent sections of the chapter that deal with a sustainability research agenda in Africa, capacity development requirements related to sustainability science, and an African vision in this field.

The attainment of sustainable development in the selected countries (Africa and the developing world) will not be reached without a sustained and clearly directed effort to develop local research and innovation capacities able to produce and utilize knowledge. The study on Ethiopia clearly illustrates that, in the context of the linkages between water, energy, industrialization, urbanization and demographics, research and innovation, coupled with good governance and multistakeholder dialogue, are positive drivers of change. As a result, sectors such as ICT and agriculture are reported to be flourishing from the perspective of innovation. While the above-mentioned linkages

5 In 2017, South Africa hosted the School of Sustainability Science Workshop of the UNESCO Intergovernmental Science Programme on Social Transformations (MOST), which published a policy paper based on the discussions (UNESCO, 2017).

between water, energy and the food nexus were identified during the UNESCO-Sida workshops in all countries studied as priorities, there are also differencess in the relative paths towards the application of sustainability science, as illustrated below.

8.6.1. Action-driven research and innovation can drive change

The Ethiopian chapter justifies the approach promoted in the context of Future Earth to focus on the nexus between food, water and energy issues,[6] which pervades the discussion of all country reports. The interdependencies between water, food and energy, discussed as a nexus by several authors (Hoff, 2011; Hussey and Pittock, 2012; Marsh, 2008) are numerous and complex, and need to be approached in an integrated manner by research. What makes the situation even more paradoxical is that while Africa is a major supplier of food to the world, its demand grows at the same time so that the resources required to meet this demand are, in several cases, dwindling (Rockström et al., 2009; Brito and Stafford Smith, 2012).

The chapter illustrates the predicament in the UNESCO guidelines with regard to the application of sustainability science, according to which the approaches of basic, fundamental science versus applied research are not mutually exclusive (UNESCO, 2018*a*) and that action-driven research is urgently needed. The authors of the chapter remind us that in Ethiopia, if adequate funding is not allocated for conductive explorative research and innovation, there will be fewer technically qualified staff and researchers, and partnerships between public research and private entities will also suffer.

In Kenya the pyramidal and nested organization of the STI system – a national commission for STI, a national innovation agency and a national research foundation – appears to have been conceived in a strategic manner, in terms of a results-based approach to research and innovation in support of sustainability. Moreover, the multi-ministerial nature of STI efforts in Kenya indicate a vision to mainstream research and innovation and to recognize the nexus nature of sustainability problems, on the one hand; on the other hand, the authors point to a lack of coordination among concerned ministries.

The Export Processing Zones initiative, 'which offers manufacturing firms incentives and low-barrier environments to access export markets and foreign direct investment opportunities' is an example of Kenya's approach to innovation incubators. There are also clear and financially significant efforts to establish innovation parks. The notion of innovation incubators is also referred to within the Ethiopian chapter. In this regard, the proliferation of initiatives to establish new 'environmentally-minded' science parks and technology business incubators is noteworthy.

The Tanzanian chapter states that Tanzania's National Research and Development Policy aims to address sustainability problems, including the provision of a framework for the commercialization of research results. Mainstreaming the environment into sectoral policy through the National Environmental Policy is also seen as a milestone towards implementing sustainability in Tanzania. Limitations to human and infrastructural resources are, however, hampering the contribution of STI to sustainable development.

In Tanzania, the preparation process of the National Research Agenda for both the inland and Zanzibar archipelago appears inclusive and transdisciplinary, and should be commended. These are indeed seeds of sustainability science in action, but they may not be enough to guarantee a comprehensive approach to mainstreaming sustainability science in support of the relevant goals and targets of the 2030 Agenda for Sustainable Development, as discussed above.

Photo 8.5. Group of farmers with International Rice Research Institute extension workers, Burundi.
© UNESCO/J. Chaves-Chaparro

However, as indicated in Chapter 2, research efforts are not properly aligned with this policy and social prioritization, nor is the multi- and interdisciplinary setting strong enough to support this nexus of water, food and energy. All these themes are part of a cluster that has seen the lowest annual average growth in the last ten years as compared to the growth in literature. Agricultural investment has decreased in the past year and, out of the five countries covered in this publication, only Ethiopia has

6 Cf. http://www.futureearth.org/future-earth-water-energy-food-nexus.

invested more than 20%, of its budget, attaining the regional objective of 1% in the Maputo Declaration of 2013, while Kenya and Uganda have invested 1.2% of their agriculture GDP in R&D.

Donor-driven research agendas in many sub-Saharan African countries might be causing this misalignment between socio-political and scientists' choice of research and innovation subjects, as discussed in the Ugandan chapter. Crises are also a main source of disruption in the financing of R&D, as humanitarian action is mainly directed to urgent actions and less on creating long-term resilience through planning and mitigation of conflicts or climate change impacts.

Therefore, there is a need to enhance the science-policy-society interfaces, as well as to adopt STI policies and instruments to specific interdisciplinary regional and national research agendas, in order to be able to address societal needs and to ensure the endogenous, holistic design of African self-development sustainability paths. This process will also be of great importance in enlarging and enriching the global notion and monitoring of the sustainable development transformation. In this sense, the need for improved and better-adapted monitoring systems and indicators, especially for developing countries, is of great importance to understanding and promoting the tremendous potential of the region's contribution to global sustainability.

8.6.2. Co-designing knowledge for inclusive development: The role of indigenous and local knowledge

Should the SDG be reached within the next two decades, great strides must be made towards inclusive development in line with the general principle of 'no one left behind'. It has been pointed out by Aguirre-Bastos et al. (2015) that without new and different strengths in science, research, technology and innovation (SRTI), developing countries will not be able to face the challenge of inclusion, and for this to occur new policies must be put in place.

Such policies require the integration of analytical and methodological tools to enhance the double dimension of inclusion: the inclusiveness of the innovation process (inclusive innovation), and innovation for social inclusion. The interest in better defining policy for the integration of the double dimensions of the inclusion-innovation nexus also arises, most importantly because of the prominence of the complex problems which must be addressed, and which defy standard policy approaches.

It is also argued (Aguirre-Bastos et el., 2017) that there is a need for a policy tool as a distinct policy-making instrument, in order to help bridge innovation and social inclusion policies. Developing such a new policy tool requires that the excluded communities be potential consumers, producers and business partners as well as innovators. This view highlights the need to move towards a 'dialogue between knowledges' as a policy tool.

The dialogue is a space where people meet beyond established hierarchies and social and cultural boundaries, building trust between the parties involved, enabling self-reflection among the actors and from where ideas, understandings, opportunities and creative thinking emerge. It is a form of co-production of knowledge (Pohl et al., 2010) addressed to bring disciplinary researchers and local indigenous, non-academic actors together and overcoming two seemingly incompatible goals: credibility (scientific adequacy) and legitimacy (respect for diverging values and beliefs).

Yampara (2010) envisions the dialogue as 'ancestral wisdom and knowledge plus occidental wisdom and knowledge equals a profound and renovated knowledge'. Such a vision is a combination of the two civilizing value systems *starting from a position of equality,* and not the asymmetry that exists between them, and particularly different from the classic asymmetric interaction between indigenous communities and researchers.

The dialogue also provides for solutions in the form of social innovations, defined as new ideas (products, services and models) that fulfil unmet social needs. There exist several analyses that suggest that restrained entrepreneurship policy approaches, connected to local innovation, may improve social inclusiveness and the likelihood of productive outcomes, which in turn directs alert entrepreneurs towards productive rather than destructive pursuits.

In the above context, the identification of ancestral knowledge is key to the success of an integrated policy and all country studies give different weights to its relevance.

The chapter on Ethiopia refers only peripherally to the role of indigenous and traditional knowledge and ethnic tensions. Yet, the organization of human uses of the landscape and the provision of ecosystem services in the country are largely driven by local knowledge and cultural drivers influencing different kinds of land use (IAASTD, 2009) that are in conflict with foreign agriculture investors in the Gambella area.

The Kenyan chapter recognizes the relevance of multiple knowledge systems for both research and education. The authors state that recognition of complementarities in formal and traditional knowledge systems (to which they refer as 'experiential knowledge') may be key to the success of sustainability science. Paradoxically, indigenous knowledge systems in Kenya appear to be more dynamic in (potentially)

Photo 8.6. Agricultural extension community projects are key for sustainable development in a continent where farming is the biggest economic sector and main source of employment.
© UNESCO/J. Chaves-Chaparro

responding to sustainability challenges than conventional science. The mapping of indigenous knowledge in Kenya, the signing of relevant agreements for the preservation of such knowledge, and the recent dedicated policy on traditional knowledge and genetic resources are clearly a sign that the contribution of indigenous and local knowledge systems has been captured within legal and policy frameworks.

The findings on Kenya also refer to cooperation and synergies among knowledge systems. The narrative description of such synergies is indeed already an important testimonial to illustrating the contribution of indigenous and local knowledge to the sustainability concept itself. On the other hand, there is a need to map and analyse such evidence in a systematic manner, as demonstrated by expert work conducted in the context of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (Pascual et al., 2017).

The Kenyan chapter refers to attempts to integrate indigenous knowledge into formal education and notes that such integration still faces major barriers in terms of communication between the different systems. The authors state that indigenous knowledge systems were found to be critical to addressing sustainability challenges; yet, it is only through a systematic assessment of their contribution to the latter that indigenous and local knowledge is likely to find a 'safe space' in policy contexts related to sustainable development (Pascual et al., 2017).

In some case studies, the role of indigenous and local knowledge also seems to pervade the area of innovation. The authors of the related chapter report that, in Ethiopia, while innovation curricula tend to be based on conventional engineering education, numerous innovation initiatives (especially in manufacturing) rely on indigenous and local knowledge. The authors also warn us about the risks of these innovative initiatives becoming dispersed and isolated (Gebreeyesus and Mohnen, 2013). At the same time, the value-chain approach of innovation in small businesses enterprises that entails local knowledge is demonstrated by high-quality products that appeal to both national urban and international markets.

8.6.3. The international aspect of sustainability science

Today, the internationalization of science in its different modalities constitutes a powerful development instrument. It has grown exponentially in recent years and has become a

central issue in the research and innovation policies of several countries (Gacel-Ávila et al., 2018). As an example, according to the 2015 *UNESCO World Science Report*, researchers have never been so mobile in history.

UNESCO has stated the need to recognize the international dimensions of research and development and, in this regard, should do everything possible to help scientific researchers participate in international research efforts, especially on sustainability and global change issues.

However, scientists in developing countries rarely have the opportunity to participate in decisions about 37 global science agendas. In addition, bilateral donors and institutions often exert a strong influence on the policy choices of developing countries, including those regarding STI systems.

Many experts saw the importance of not only identifying emerging issues, but also ascertaining ways in which to address them. How this could be done should be further discussed.

Identifying sustainable development trends, identifying and acting on emerging issues and improving the link between international assessments and national policy development is key for the countries in the region. Also of importance is the creation of an open access database of timely spatial data related to sustainability to help authorities and scientists in less developed countries to monitor progress; and an open access platform where scientists can share data and research outcomes on sustainability.

As already discussed above, sustainability science is a global effort (Elsevier, 2015) and phenomena such as brain-drain or the lack of intraregional cooperation continue to hamper outcomes. The five country studies show that efforts are being made to promote intraregional and South-South scientific cooperation, but these still fall far short of the goals.

Given the high levels of biocultural diversity in the Africa region, sustainability science, by its very nature, provides a unique opportunity to co-produce local and global knowledge, a tailor-made approach to the sustainable development concept and pathways for social transformation.

Coupled with effective policy instruments, sustainability science can help mobilize and retain human capacities, reducing brain drain and supporting inclusive development through knowledge-based business and opportunities for decent work. The extended African diaspora and ICT's swift development in the region are also key drivers for the internationalization of the African research and innovation outputs.

8.7. Policy responses and the sustainability science approach

In 2013, the African Union (AU) member states crafted an Africa-driven vision 'Agenda 2063: The Africa We Want' (AUC, 2015), which outlined how the African continent should look in 50 years based on the pillars of wealth generation, regional integration and attainment of a peaceful society, all driven by Africans. In 2015, the UN member states unanimously adopted the Agenda, which balances the dimensions of economic, social and environmental development, underpinned by good governance. Both agendas include specific sets of goals.

These goals broadly converge on social and human capital development, inclusive economic growth, peaceful societies, accountable institutions and environmental sustainability dimensions.

Sustainability science shall be instrumental to the implementation of both agendas by promoting intraregional and international cooperation to provide evidence to empower such themes as inequality (between and within nations), sustainable management of land ecosystems (desertification, biodiversity and land degradation), responsible consumption and production, and urgent climate action.

At the national level, the science policy interface is also to be enhanced to have better informed policies and priority setting; the same for research and innovation areas. The **Ethiopian** chapter demonstrates that the country has policy frameworks in place to deal with *inter alia* poverty, growth, climate change and education. Yet, there seems to be a disconnect between the nexus nature of the sustainability problems encountered and the more vertical nature of the policy frameworks in place in Ethiopia. Sustainability science endeavours not only to study issues through a multi- and interdisciplinary lens; it also calls for policy responses to reflect the multidimensional nature of the problem when addressing it (Kauffman and Aricò, 2014).

The **Kenyan** chapter also links issues related to sustainable development with poverty, inequalities, population growth, urbanization and rapid industrialization. In this regard, there seems to be an adequate and conducive policy framework for sustainable development in Kenya, represented by Kenya's Vision 2030, and in the broader context of 'Agenda 2063: The Africa We Want'.

Kenya's Vision 2030 'aims to transform Kenya into a newly industrializing, upper middle-income country providing a high-quality life to all its citizens by the year 2030', considering the

three pillars of sustainable development. In this context, STI is seen as a central element and engine to realize the vision.

In Kenya, efforts have been made to create the institutional conditions for sustainability science. The STI policy framework is being mapped against the degree of recognition and mainstreaming of traditional knowledge; and cooperation barriers among disciplines and institutions that generate knowledge of relevance to sustainable development (industry, universities and other research institutions).

In Kenya, the identified key drivers of positive change seem to be in contradiction with unresolved drivers hampering sustainable development, namely drought, famine, fiscal slippages and misconduct, currency volatility and political instability. This matter deserves urgent attention, as the country is gradually shifting from agriculture to a services sector-based economy.

Poverty and inequalities clearly play a role in relation to sustainability in Kenya. The questions posed in the Kenyan chapter in relation to creating the conditions for sustainability are legitimate but require more evidence and should be addressed through further research in the area. In fact, sustainability science also entails a research phase, going beyond conventional STI diagnoses. For example, there seems to be a need for a more in-depth analysis of the dynamics of the multistakeholder process associated with the development of Kenya's Vision 2030.

Photo 8.7. Water management is vital in Africa and requires international cooperation, as some 85% of the continent's resources are comprised of large river basins that are shared between several countries. The photo shows the Blue Nile in Ethiopia, the source of most of Egypt´s Nile water. © UNESCO/J. Chaves-Chaparro

The Kenyan chapter is also quite illustrative from the perspective of various sustainable development policies that seem to have been crafted and implemented upfront (the Development Plan of the 1970s, the one from the 1990s, and currently the Vision 2030 of Kenya); sustainability policies should thus be underpinned by research findings, multistakeholder dialogues, and tried-and-tested practices (UNESCO, 2018*a*).

The Vision 2020 of **Rwanda** envisages a service-oriented, knowledge-based economy, with a population characterized by a middle-income status. The overall vision is framed by the notion of good governance. The vision insists on the importance of investing in education, partnerships with the private sector and the promotion of middle-class entrepreneurship, infrastructure development including telecommunication, high-value agriculture, and regional and global market integration. Additionally, it cuts across the goals of gender equality, the sustainable use of natural resources and conservation of biodiversity, and STI systems.

The integration of the economic development strategy with the poverty reduction strategy, which also includes citizens' participation and accountability schemes vis-à-vis the citizen, is also part and parcel of Rwanda's Vision 2020. Mapping the sustainable development needs of the country against the SDGs guides the development of tailored policies accordingly. Adequate legal – not just policy – frameworks, also reflecting an integrated approach to economic development, environment, biodiversity and the people, are in place.

Rwanda seems to benefit from a proper integrated framework to tackle sustainability challenges and capitalize on related opportunities. The underpinning philosophy is built on the principle that there is a need to create linkages between policy, capacity and major country issues, and to emphasize a cluster approach to interventions, not only in terms of national policies and projects but also of external relationships with the donor community and the international community at large.

The assessment and evaluation functions are also reflected in Rwanda's approach to sustainability, including through external reviews (UNESCO, 2018*a*).

The 'home-grown' initiatives described in the Rwandan chapter constitute a commendable initiative for the development of 'social maps' by communities themselves, against which to identify and implement concrete solutions. The important role of the *girinka* practice, for example, provides a culture-based solution to a dimension of sustainability, namely food security. The Rwandan chapter suggests that indigenous knowledge can play a critical role in transforming the technology to adapt it to local solutions. The Rwanda model also points to reducing inequalities in access to science by women.

While the approach pursued by Rwanda since the early 2000s has allowed the country to fully embrace the notion of sustainable development, further challenges lie ahead, namely in relation to climate change, environmental degradation and the need to conserve biodiversity.

The chapter dealing with **Tanzania** provides a comprehensive description of policy frameworks put in place for the country, including in relation to science policy. An underlying question in the chapter is: 'Are such policy frameworks and institutional arrangements of a top-down nature?'

Photo 8.8. Education for sustainable development is vital in highly populated islands with conflicting demands for natural resources, as in Zanzibar.
© UNESCO/J. Chaves-Chaparro

In Tanzania, inequalities related to access to education, health and gender affect the creation of the improved conditions crucial to the success of sustainable development interventions. The Tanzanian 2016–2021 Development Plan refers to the need to build a foundation for structural change, including social inclusive development processes, through mutual synergies between infrastructural development and human resource development.

Local innovation efforts in Tanzania are intended to be pursued through a combination of measures: on the one hand, there is a recognition of the dependence of people's livelihoods on primary resources such as forest wood, and of the degradation of land and the ensuing degradation of ecosystem services such as agricultural production, water availability and water quality. On the other hand, there is a clear commitment towards sustainability from a legal and policy perspective: the conventional legal framework is complemented by a sustainability policy framework that applies to multiple sectors, spanning from environment to environmental quality, agriculture and more. Decentralization of governance, in terms of both decision-making and implementation, as well as multistakeholder participation, complete the Tanzanian approach to 'walking the talk' in relation to Tanzania's commitment to implementing the Rio Conventions. This approach, although less thorough and integrated than the one pursued in Rwanda, shows potential for paving the way for the application of sustainability science in Tanzania.

In **Uganda**, low-tech agriculture is recognized as an important sector. The way in which the problem is framed is consistent with the current approach of Future Earth in relation to the water-energy-food nexus.[7]

Internal and border conflicts in the country act as a clear deterrent to development, and the large number of refugees adds to the pressure on resources and environment. Food insecurity, climate change (drought), malnutrition, land degradation (also due to inappropriate management), deforestation, poor farming, lack of education, soil erosion and biodiversity loss are the main obstacles to achieving sustainability in the country.

Yet, proactive and affirmative action policies are applied. These include: policies related to the role of women in society based on a strong gender analysis; mainstreaming climate change predictions into planning; and developing an adequate sustainable development framework.

The Uganda Vision 2040 reflects the main dimensions of sustainable development in an integrative manner.

Uganda has had a tradition of championing higher education and industrialization since the 1960s, and STI agendas since the 1970s. One of the objectives of the 2009 National Science, Technology and Innovation Programme of Uganda is to help overcome STI sector-based barriers; to this end, the authors of the Ugandan chapter stress the importance of adaptive STI policies. The chapter presents important pillars/principles/approaches of sustainability science in action, as follows:

- The need for a national research agenda that overcomes the limitations of conventional STI approaches. There

7 Cf. http://www.futureearth.org/future-earth-water-energy-food-nexus.

is a strong emphasis on the need to overcome the compartmentalization of interactions and actively foster dialogue among disciplines (Hackmann et al., 2014);

- The importance of interactions of universities with communities;[8]
- The importance of STI reviews.

At the same time, basic considerations in terms of lack of human and infrastructural resources for science must also be considered. Moreover, the Ugandan chapter states that sustainability research tends not to receive significant funding, which reflects a more general point on the difficulties faced when promoting interdisciplinarity. As such, research in Uganda's universities is often labelled as 'science for sustainability' instead of 'science of sustainability' (Spangenberg, 2011).

In the face of fragile livelihoods, collective action, mutual responsibility and alliance-building to strengthen local economic relationships are as critical for security as shaping local decision-making and holding institutions to account. How such collective economic and political agency is sequenced and sustained, and how individual economic gain affects the propensity towards collective action, are questions to pursue further. If 'thin' one-dimensional solutions to global poverty and inequality need to be replaced by thicker strategies (Edwards and Sumner, 2015), these cases, still unfolding, are context-specific examples of how that is being done.

8.8. Co-designing science in Africa: Policy recommendations

8.8.1. Unlock the transformational potential of sustainability science

The UNESCO *Guidelines on Sustainability Science in Research and Education* call for any type of research to 'respond to the interdependent, complex and mutually reinforcing character of natural, social and cultural ongoing, global and local challenges' (UNESCO, 2018*a*).

The Guidelines encourage framing the work of sustainability scientists, especially young scientists, through interdisciplinarity. In addition to interdisciplinarity, the Guidelines recommend the following 'ingredients for success'[9] to mainstream sustainability science into research:

a) Involve multiple stakeholders, including funders of research, policy-makers and civil society, in the co-definition of the problem, which in turn will inform the definition of key research questions.

b) Ensure adequate structural requirements for mainstreaming sustainability science, namely additional time and resources for individual scientists and networks of scientists to cross-fertilize and deliver enhanced research capacities in terms of inter- and transdisciplinarity, and co-design (co-definition of the problem, definition of goals and visions and establishment of working relationships among the multiple stakeholders involved, including the scientists themselves).

c) Evaluate different forms of knowledge and their relevance and compatibility in relation to the problems being studied.

d) Establish multistakeholder evaluation panels and use adequate indicators to assess and monitor progress, outputs and impacts of the projects.

e) Foresee dedicated options for career development for scientists involved in inter- and transdisciplinary research projects, including dedicated scientific evaluation frameworks and approaches.

Photo 8.9. Communities of Indigenous peoplec have been able to preserve natural habitats for centuries, and their knowledge is key to sustainable development.
© UNESCO/J. Chaves-Chaparro

8 In this regard, it is noteworthy that this aspect has been studied in as different a context as Japan, through the concept of 'resident scientist' (Sato, personal comm.) and 'decision science' (Yahara, personal comm.).

9 Term chosen by the authors of this chapter.

From the analysis of the quest for sustainable development goals in the African countries studied, the following general observations can be derived:

a) There is a greater involvement of stakeholders in co-design than in other regions, specifically in the nexus of agriculture, energy, water and innovation.

b) Sustainability science in the countries studied tends to be focused on science for sustainability rather than science on sustainability.

c) Interdisciplinarity may be limited in scope but the potential for transdisciplinarity is obvious and should be capitalized upon.

d) Relevant forms of knowledge other than scientific knowledge tend to be socially well-recognized. This opportunity should be capitalized upon to assess their relevance to the sustainability challenges faced by the countries concerned.

e) Adequate instruments and structural requirements for sustainability science in the countries studied are generally lacking, including devoted funding opportunities, evaluation approaches and career opportunities for scientists in general, and women in particular.

f) Sustainability issues differ greatly for rural and urban areas; stronger links should be established between scientists/innovators and rural communities to address specific needs, including those of women, youth and other vulnerable populations (including refugees).

g) A bigger critical mass of scientists and related institutional capacities better connected with society should be built.

h) Additional intraregional cooperation between scientists and other stakeholders should be promoted and support provided to include African researchers in global debates on sustainability.

With regard to the above, there is also a need to further assess the capacity development requirements and related opportunities for mainstreaming sustainability science in Africa, starting with the countries studied and reported upon in the previous chapters. This will maximize the potential transformational character of sustainability research in Africa, for the realization of sustainable development goals in the continent.

8.8.2. Capacity development and human resources

'Human capital' refers to the knowledge, skills and attributes that are embodied in each person and that facilitate the creation of different forms of well-being (Keeley, 2008). The benefits of human capital are also broad: they are both economic and social, and they may include both the person making the investment and the community to which they belong. Considering the specific context of the region and in particular the five countries under study – i.e. having the youngest population in the world, long-term unemployment rates, high natural capital and very diverse value systems – the human capital is key to achieving the SDGs in the region (AUC, 2015).

Capacity development and technology transfer are critical elements of sustainable development (Juma and Konde, 2002). Studies of African experiences related to brain drain, development of scientific networks and international collaborations involving African scientists point to several measures to foster capacity development and consolidate the capacity infrastructure for realizing sustainable development in Africa (UNSG SAB, 2016).

The African report of Sustainable Development Goals (UNECA, 2017*b*) prioritizes cross-cutting issues such as peace, governance and institutions, financing, capacity-building and technology transfer. In fact, developing, strengthening and valorizing scientific capacity in general relies on a range of measures and policy instruments, several of which are of a synergistic nature. These entail the strengthening of *inter alia* research infrastructures (laboratory equipment, field instruments), manuals and reference materials, observation facilities, and IT capabilities for data storage and processing.

Transferring knowledge and technology is also important for strengthening infrastructural and human capacity. In this regard, access to knowledge entails *inter alia* access to information related to opportunities for research funding in the form of calls for project proposals, open access to data, international scientific collaborations in the field and through the production of joint scientific publications, study grants, technical training, and participation in workshops, seminars and conferences.

The countries studied in this book are experimenting with opportunities for public-private partnerships in research. In Tanzania, for example, research on nexus issues (health/environment/water/energy) benefits from a clear demand from decision-makers. This has led to the establishment of the Nelson Mandela African Institute of Science and Technology (a 'category II' – i.e. affiliated – centre of UNESCO), also referred to as the 'Academy for Society and Industry'. The authors of the Tanzanian chapter report on multi- and transdisciplinary research being pursued in this institution, involving mixed research groups composed of scientists as well as representatives of industry and other segments of society. Approaches like the one described

for Tanzania are key to knowledge transfer and for promoting and mainstreaming innovation into sustainability.

The development of adequate capacities to implement sustainability science also requires training the next generation of sustainability scientists through interdisciplinary and multidisciplinary education. For example, the increase in the number of enrolled university students since the early 2000s in Kenya is impressive, but multidisciplinarity in education is lagging.

The UNESCO *Guidelines on Sustainability Science in Research and Education* (UNESCO, 2018*a*) encourage the following measures to mainstream sustainability science in higher education:

a) Higher education institutions should embrace sustainability science as part of their core mission. Sustainability should be reflected in all curricula, and capacities for science education in general should be improved. Open education resources should be promoted, and a more balanced approach to research and teaching should be pursued.

b) Individual researchers and teachers should embrace a silo-less culture of academic disciplines and expose young researchers to training in sustainability science thinking.

c) Governments should ensure appropriate policy-enabling environments and institutions to promote higher education compatible with the nature and goals of sustainability science, through reforms in law on higher education, the development of indicators for academic and university performance in sustainability science, and the allocation of funding for teaching in sustainability science.

Photo 8.10. The promotion of social innovation and enterpreneurship starts at an early age.
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d) Society at large and communities should foster the sustainability literacy of every individual and facilitate the engagement of individuals in 'citizen science'.

8.9. A vision for the region: Africa leading the way in sustainability science

It is interesting to note the adoption of future visions in all five countries with the overall goal of attaining a higher economic level within the next two or three decades. Many of these goals are in line with the UN Sustainable Development Goals as well as Africa's future vision, such as that depicted in Vision 2063 (AUC, 2015).

The national goals and SDGs are to be delivered by 2030. Africa cannot wait to realize those and can indeed contribute significantly to broaden the concept of a sustainability approach and collect evidence needed to co-design appropriate policies and methodologies to capture the interactions between different dimensions of, and to co-produce, the most appropriate solutions to the sustainability challenge. This requires that Africa be recognized as a sustainability priority, for research and for development.

One of the most positive and forward-looking conclusions of this book is the vision that Africa lead in the application of sustainability science to solve societal problems and maximize opportunities for sustainable development. Several characteristics support this conclusion: an interdisciplinary and collaborative mindset, a young and innovative population and high biocultural diversity.

At the risk of presenting an overly simplistic recipe for success, sustainability science requires tailor-made measures, starting by mainstreaming inter- and transdisciplinary science into research and education, and ensuring the necessary legal, policy and institutional enabling framework to deliver the desired results. The reference in the 2008 Science, Technology and Innovation Policy of Kenya to 'encourage and support collaborative, multidisciplinary scientific research in universities and other academic, scientific and engineering institutions' is key to the quest of operationalizing sustainability through research and education.

Another important condition for success is the adequate financial effort in support of sustainability science. The example of Kenya illustrates the need for, but also the difficulty in assessing, the Gross Domestic Expenditure on R&D (GERD), especially the

contribution from external sources, and this is often the case for many countries in the world (UNSG SAB, 2016).

Scientific performance can also be assessed by analysing the number of publications by science fields or combinations of them. In this regard, it is necessary and important to measure trends in scientific publications per topic and multidisciplinary areas related to sustainability, rather than conventional disciplines. The level of scientific collaborations is also a central indicator, as scientists from countries that feature low in terms of number of individual scientific publications may be actively contributing to publications produced in other countries (IOC, 2017).

Given that sustainability science is a very high-impact domain of research, with a double impact according to Elsevier, it should become a priority to increase the low global share of publications in the region that accounted for just 2.6% (and especially of SSA, which accounted for only 1.2%) (UNESCO, 2014), although it corresponds to 12.5% of the global population.

Based on the flexible and holistic value system of this very young region, interdisciplinary inclusive research and education towards social innovation, knowledge co-production, and transfer of knowledge generated for the creation of decent jobs for all can be a great contribution to the regional sustainable development agenda.

Underpinned by the above considerations, the multistakeholder workshops on sustainability science organized by UNESCO in the countries studied, with the support of Sida, were important in highlighting and illustrating in a systematic manner the need for a bottom-up approach to the design of sustainability solutions, based on experiments driven by social objectives, involvement of multiple stakeholders and bottom-up innovation.

Photo 8.11. River Ewaso Ng'iro

References

AfDB. 2016. *Jobs for Youth in Africa: Strategy for Creating 25 Million Jobs and Equipping 50 Million Youth 2016–2025*. African Development Bank and the High 5.

Aguirre-Bastos, C., Bortagaray, I. and Weber, M. 2015. Inclusive policies for inclusive innovation in developing countries: The role of future oriented analysis. Paper presented to the XIII GLOBELICS International Conference, Havana, 23–25 September.

Aguirre-Bastos, C., Cummings, A., Candanedo, D., Dutari, M. and Villanueva, A. 2017. A new generation of research and innovation policy in Panama: Overcoming the lineal model and facing the challenge of inclusive development. Paper presented to the IV Atlanta Conference on Research and Innovation Policy, Atlanta, GA, November.

Aricò, S. 2014. The contribution of the sciences, technology and innovation to sustainable development: The application of sustainability science from the perspective of UNESCO's experience. *Sustainability Science*, Vol. 9, pp. 453–62.

AUC. 2003. *Maputo Declaration on Agriculture and Food Security in Africa*. Available at: http://www.nepad.org/resource/au-2003-maputo-declaration-agriculture-and-food-security

AUC. 2015. *Agenda 2063: The Africa we want. First Ten Years Implementation Plan 2014–2023*. Addis Ababa, AUC.

Bendix, J., Beck, E., Brauning, A., Makeschin, F., Mosandl, R., Schen, S. and Wilcke, W. (eds). 2013. *Biodiversity and Environmental Change in a Tropical Mountain Ecosystem of South Ecuador*. Berlin, Heidelberg, Springer-Verlag.

Borgen Project. 2017. 10 important facts about education in Africa. *Borgen Project Blog*. Available at: https://borgenproject.org/10-facts-about-education-in-africa/

Brito, L. and Stafford Smith, M. 2012. *State of the Planet Declaration*. Planet Under Pressure conference, London 26–29 March. Available at: www.igbp.net/publications/stateoftheplanetdeclaration.4.6b007aff13cb59eff6411baa.html

Diaz, S., Demissew, S., Carabias, J. and Eyzaguirre, P. 2015. The IPBES conceptual framework: Connecting nature and people. *Current Opinion in Environmental Sustainability (COSUST)*, Vol. 14, pp. 1–16.

Diop CA. 1974. *The African Origin of Civilization: Myth or Reality.* Lawrence Hill and Company, Paris.

Edward, P. and Sumner, A. 2015. *New Estimates of Global Poverty and Inequality: How Much Difference Do Price Data Really Make?* CGD Working Paper 403. Washington, DC: Center for Global Development. http://www.cgdev.org/publication/new-estimates-global-poverty-and-inequality-how-muchdifference-do-price-data-really

Elsevier. 2015. *Sustainability Science in a Global Landscape*. Elsevier and SciDevNet.

FSIN. 2018. *Global Report on Food Crises 2018*. Rome, FSIN (FAO)

Gacel-Ávila, J., Aguirre-Bastos, C., Madera, I., Marmolejo Cervantes, F., Rodríguez-Rodríguez, S., Sebastián, J., Thelier, J., Rodriguez, M. J. and Tunnermann Bernheim, C. 2018. *Educación superior, internacionalización e integración en América Latina y el Caribe*. Caracas, Editorial IESALC–UNESCO.

Gebreeyesus, M. and Mohnen, P. 2013. Innovation performance and embeddedness in networks: Evidence from the Ethiopian footwear cluster. *World Development*, Vol. 41, pp. 302–16.

Hackmann, H., Moser, S. C. and St. Clair, A. L. The social heart of global environmental change. *Nature Climate Change*, Vol. 4, pp. 653–55.

Hoff, H. 2011. *Understanding the Nexus*. Background paper for the Bonn2011 Conference: The Water, Energy and Food Security Nexus. Stockholm Environment Institute, Stockholm.

Hussey, K. and Pittock, J. 2012. The energy–water nexus: Managing the links between energy and water for a sustainable future. Ecol. *Soc., Vol. 17*, No. 1, p. 31.

IAASTD. 2009. *International Assessment of Agricultural Knowledge, Science and Technology for Development: Sub-Saharan Africa (SSA) Report*. Volume V, Sub-Saharan Africa. B. D. McIntyre, H. R. Herren, J. Wakhungu, R. T. Watson (eds) Island Press, 2009.

ICSU. 2005. *Harnessing Science, Technology, and Innovation for Sustainable Development.* Paris, ICSU. https://council.science/cms/2017/05/Consortium_Report.pdf

ICSU-ISSC. 2015. *Review of Targets for the Sustainable Development Goals: The Science Perspective*. Paris, ICSU. https://council.science/cms/2017/05/SDG-Report.pdf

ILO. 2018. *Women and Men in the Informal Economy: A Statistical Picture*. Third edition. Geneva, ILO. http://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/publication/wcms_626831.pdf

IOC (Intergovernmental Oceanographic Commission of UNESCO). 2017. *Global Ocean Science Report. The Current Status of Ocean Science around the World*. Paris, UNESCO.

Juma, C. and Konde, V. 2002. *Technical Change and Sustainable Development: Developing Country Perspectives*. American Association for the Advancement of Science (AAAS) Annual Meeting and Science Innovation Exposition. Boston MA, 14–19 February.

Kauffmann, J. and Aricò, S. 2014. New directions in sustainability science: Promoting integration and cooperation. *Sustainability Science*, Vol. 9, No. 4, pp. 314–18.

Keeley B. 2008. *Human Capital How what you know shapes your life*, OECD, Paris.

Maputo Declaration. 2003. *The Maputo Commitments and the 2014 African Union Year of Agriculture*. ONE.org/40chances.

Marsh, D. 2008. The water–energy nexus: A comprehensive analysis in the context of New South Wales. Dissertation. Sydney, NSW: University of Technology. Retrieved from http://epress.lib.uts.edu.au/scholarlyworks/bitstream/handle/2100/1075/OriginalFile.pdf?sequence=4

Medina, L., Jonelis, A.W. and Canguk, M. 2017. *The Informal Economy in Sub-Saharan Africa: Size and Determinants*. IMF Working Paper. https://www.imf.org/en/Publications/WP/Issues/2017/07/10/The-Informal-Economy-in-Sub-Saharan-Africa-Size-and-Determinants-45017

Millennium Ecosystem Assessment. 2005. Policy responses. *Biodiversity*, Vol. 3, Chapter 5. Washington D.C., Island Press, pp. 119–72.

Mogues, T., Yu, B., Fan, S. and McBride, L. 2012. *The Impacts of Public Investment in and for Agriculture. Synthesis of the Existing Evidence*. ESA Working Paper 12-07. Rome, ESA (FAO). http://www.fao.org/docrep/016/ap108e/ap108e.pdf

OECD-FAO. 2016. Agriculture in sub-Saharan Africa: Prospects and challenges for the next decade. *OECD-FAO Agricultural Outlook 2016–2025*. OECD/FAO.

Pascual, U., Balvanera, P., Diaz, S., Pataki, G., Roth, E. et al. 2017. Valuing nature's contributions to people: the IPBES approach. *Current Opinion in Environmental Sustainability*, Vol. 26–27, pp. 7–16.

Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurung, G. S., Schneider, F., Speranza, C. I., Kiteme, B., Boillat, S., Serrano, E., Hadorn, G. H. and Wiesmann, U. 2010. Researchers' roles in knowledge co-production: Experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Science and Public Policy*, Vol. 37, No. 4, pp. 267–81.

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E .F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J. A. 2009. A safe operating space for humanity. *Nature*, Vol. 461, pp. 472–75.

UNSG SAB (Scientific Advisory Board of the UN Secretary-General). 2016. *The Future of Scientific Advice to the United Nations*. Paris, UNESCO.

SDG Centre for Africa and SDSN. 2018. *Africa SDG Index and Dashboards Report 2018*. http://unsdsn.org/wp-content/uploads/2018/07/AFRICA-SDGS-2018-Complete-Report-WEB.pdf

Spanenberg, J.H. 2011, Sustainability science: a review, an analysis and some empirical lessons, *Environmental Conservation* https://www.cambridge.org/core/journals/environmental-conservation/volume/317D2279C1081C999671B41A3CEE03B3, https://doi.org/10.1017/S0376892911000270.

Stiglitz, J. E., Sen, A. and Fitoussi, J.-P. (coordinators). 2009. *Report of the Commission on the Measurement of Economic Performance and Social Progress*. Paris, OFCE. www.stiglitz-sen-fitoussi.fr

Tekwe, C. D., Carter, R. L., Cullings, H. M. and Carroll, R. J. 2014. Multiple Indicator – Multiple Causes Measurement Error Models. *Stat Med*, Vol. 33, No. 25, pp. 4469–81.

UN. 2014. *Prototype Global Sustainable Development Report 2014*. Available at: https://sustainabledevelopment.un.org/index.php?menu=1621

UNDP. 2017. *Africa's Defining Challenge*. http://www.africa.undp.org/content/rba/en/home/blog/2017/8/7/africa_defining_challenge.html

UNECA. 2017*a*. *Workshop on the implementation of the SDG indicators framework*. Cape Town, 19–20 January.

UNECA. 2017b. Africa Sustainable Development Report: Tracking Progress on Agenda 2063 and the Sustainable Development Goals, Economic Commission for Africa, Addis Ababa, Ethiopia

UNESCO. 2012. *Human Origin Sites and the World Heritage Convention in Africa*. N. Sanz, (ed.). Paris, UNESCO/World Heritage Convention.

UNESCO. 2014. *UNESCO Medium-Term Strategy 2014–2021*. Paris, UNESCO. Available at: http://unesdoc.unesco.org/images/0022/002278/227860e.pdf.

UNESCO. 2015. *World Science Report: Towards 2030*. Paris, UNESCO.

UNESCO. 2016. *World Social Science Report 2016. Challenging Inequalities: Pathways to a Just World*. Paris, UNESCO.

UNESCO. 2017. *MOST School on Sustainability Science. Promoting Castelsarrasin Research in Projects Management, Policy Research and Public Policies Development*. Cape Town, South Africa, April.

UNESCO. 2018*a*. *Guidelines on Sustainability Science in Research and Education for Implementing the SDGs*. Paris, UNESCO. Available at: https://en.unesco.org/sites/default/files/2511_17_e_sustainability_science_flyer_en_f.pdf

UNESCO. 2018*b*. *Recommendation on Science and Scientific Researchers*. Paris, UNESCO. Available at: http://unesdoc.unesco.org/images/0026/002636/263618e.pdf

UNSG SAB. 2016. *Science for Sustainable Development*. Policy brief by the Scientific Advisory Board of the UN Secretary-General, 5 October.

WHO. 2014. *The Health of the People: The African Regional Health Report*. Geneva, World Health Organization.

Wilson, C. 2017. *Disruptive Low Carbon Innovation Workshop: Synthesis Report*. Tyndall Working Paper 164. Norwich (UK), Tyndall Centre for Climate Change & Future Earth.

World Bank. 2017. *Statistical Capacity Indicators Scores*. Available at: http://datatopics.worldbank.org/statisticalcapacity

World Commission on Environment and Development. 1987. *Our Common Future*. United Nations. Available at: http://www.un-documents.net/our-common-future.pdf

Yampara, S. 2010. *Reconstitución política desde la civilización de Tiwanaku*. La Paz, Fundación Boliviana de Afasia.

Co-Designing Science in Africa:

First steps in assessing the sustainability science approach on the ground

This publication provides useful evidence supporting the need for multistakeholder discussions on how best to foster integrated, collaborative and action-oriented research to address interdependent and complex sustainability challenges in the five sub-Saharan Africa countries studied – four of the five being regional research hubs for sustainability science – and beyond.

Based on the case studies findings, the authors formulate recommendations for improving the science-policy-society interface. These are in line with the *2017 UNESCO Guidelines on Sustainability Science in Research and Education* and, more broadly with the *2017 UNESCO Recommendation on Science and Scientific Researchers*.

UNESCO recognizes that sustainable development should respond in an integrated manner to the complex challenges of today, and capitalizes on its interdisciplinary expertise and intersectoral mandate to support the implementation of the 2030 Agenda for Sustainable Development, with a special focus on developing countries and the Africa region. UNESCO's operational strategy for Priority Africa is aligned with the 2030 Agenda, which in turn fully integrates the 2063 Agenda of the African Union, as well as with the Common African Position (CAP), which foresees the mainstreaming of the sustainability science approach.

The specific focus on the African region and gender in science, combined with the balanced mix between policy and practice, makes this publication unique. We are confident that the work presented here will help to advocate for profound changes in the regional approach to STI and, through a multiplier effect, enhance the co-designing of science and innovation to a more sustainable and equitable development of Africa as well as its contribution to the co-designing of sustainable solutions for planet Earth.

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