African Open Science Platform

PART I: LANDSCAPE STUDY

PREPARED BY THE ACADEMY OF SCIENCE OF SOUTH AFRICA

FUNDED BY THE NATIONAL RESEARCH FOUNDATION, DEPARTMENT OF SCIENCE AND TECHNOLOGY, SOUTH AFRICA

12 AUGUST 2019

AFRICAN OPEN SCIENCE PLATFORM – LANDSCAPE STUDY

EXECUTIVE SUMMARY

This report maps the African landscape of Open Science – with a focus on Open Data as a sub-set of Open Science. Data to inform the landscape study were collected through a variety of methods, including surveys, desk research, engagement with a community of practice, networking with stakeholders, participation in conferences, case study presentations, and workshops hosted.

Although the majority of African countries (35 of 54) demonstrates commitment to science through its investment in research and development (R&D), academies of science, ministries of science and technology, policies, recognition of research, and participation in the Science Granting Councils Initiative (SGCI), the following countries demonstrate the highest commitment and political willingness to invest in science: Botswana, Ethiopia, Kenya, Senegal, South Africa, Tanzania, and Uganda. In addition to existing policies in Science, Technology and Innovation (STI), the following countries have made progress towards Open Data policies: Botswana, Kenya, Madagascar, Mauritius, South Africa and Uganda.

Only two African countries (Kenya and South Africa) at this stage contribute 0.8% of its GDP (Gross Domestic Product) to R&D (Research and Development), which is the closest to the AU's (African Union's) suggested 1%. Countries such as Lesotho and Madagascar ranked as 0%, while the R&D expenditure for 24 African countries is unknown. In addition to this, science globally has become fully dependent on stable ICT (Information and Communication Technologies) infrastructure, which includes connectivity/bandwidth, high performance computing facilities and data services. This is especially applicable since countries globally are finding themselves in the midst of the 4th Industrial Revolution (4IR), which is not only "about" data, but which "is" data. According to an article[1] by Alan Marcus (2015) (Senior Director, Head of Information Technology and Telecommunications Industries, World Economic Forum),

> "At its core, data represents a post-industrial opportunity. Its uses have unprecedented complexity, velocity and global reach. As digital communications become ubiquitous, data will rule in a world where nearly everyone and everything is connected in real time. That will require a highly reliable, secure and available infrastructure at its core, and innovation at the edge."

Every industry is affected as part of this revolution – also science. An important component of the digital transformation is "trust" – people must be able to trust that governments and all other industries (including the science sector), adequately handle and protect their data. This requires accountability on a global level, and digital industries must embrace

[1] https://www.weforum.org/agenda/2015/12/data-and-the-fourth-industrial-revolution/

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

the change and go for a higher standard of protection. "This will reassure consumers and citizens, benefitting the whole digital economy", says Marcus.

A stable and secure information and communication technologies (ICT) infrastructure – currently provided by the National Research and Education Networks (NRENs) – is key to advance collaboration in science. The AfricaConnect[2] project (AfricaConnect (2012–2014) and AfricaConnect2 (2016–2018)) through establishing connectivity between National Research and Education Networks (NRENs), is planning to roll out AfricaConnect3 by the end of 2019.

The concern however is that selected African governments (with the exception of a few countries such as South Africa, Mozambique, Ethiopia and others) have low awareness of the impact the Internet has today on all societal levels, how much ICT (and the 4th Industrial Revolution) have affected research, and the added value an NREN can bring to higher education and research in addressing the respective needs, which is far more complex than simply providing connectivity. Apart from more commitment and investment in R&D, African governments – to become and remain part of the 4th Industrial Revolution – have no option other than to acknowledge and commit to the role NRENs play in advancing science towards addressing the SDG (Sustainable Development Goals).

For successful collaboration and direction, it is fundamental that policies within one country are aligned with one another. Alignment on continental level is crucial for the future Pan-African African Open Science Platform to be successful. Both the HIPSSA ((Harmonization of ICT Policies in Sub-Saharan Africa)[3] project and WATRA (the West Africa Telecommunications Regulators Assembly)[4], have made progress towards the regulation of the telecom sector, and in particular of bottlenecks which curb the development of competition among ISPs. A study under HIPSSA identified potential bottlenecks in access at an affordable price to the international capacity of submarine cables and suggested means and tools used by regulators to remedy them. Work on the recommended measures and making them operational continues in collaboration with WATRA.

In addition to sufficient bandwidth and connectivity, high-performance computing facilities and services in support of data sharing are also required. The South African National Integrated Cyberinfrastructure System[5] (NICIS) has made great progress in planning and setting up a cyberinfrastructure ecosystem in support of collaborative science and data sharing. The regional Southern African Development Community[6] (SADC) Cyber-infrastructure Framework provides a valuable roadmap towards high-speed Internet, developing human capacity and skills in ICT technologies, high-

[2] https://www.africaconnect2.net/
[3] https://www.itu.int/en/ITU-D/Projects/ITU-EC-ACP/HIPSSA/Pages/default.aspx
[4] https://watra.org/
[5] https://www.csir.co.za/national-integrated-cyber-infrastructure-system
[6] https://www.sadc.int/

performance computing and more. The following countries have been identified as having high-performance computing facilities, some as a result of the Square Kilometre Array[7] (SKA) partnership: Botswana, Ghana, Kenya, Madagascar, Mozambique, Mauritius, Namibia, South Africa, Tunisia, and Zambia. More and more NRENs – especially the Level 6 NRENs[8] (Algeria, Egypt, Kenya, South Africa, and recently Zambia) – are exploring offering additional services; also in support of data sharing and transfer. The following NRENs already allow for running data-intensive applications and sharing of high-end computing assets, bio-modelling and computation on high-performance/ supercomputers: KENET (Kenya), TENET (South Africa), RENU (Uganda), ZAMREN (Zambia), EUN (Egypt) and ARN (Algeria).

Fifteen higher education training institutions from eight African countries (Botswana, Benin, Kenya, Nigeria, Rwanda, South Africa, Sudan, and Tanzania) have been identified as offering formal courses on data science. In addition to formal degrees, a number of international short courses have been developed and free international online courses are also available as an option to build capacity and integrate as part of curricula. The small number of higher education or research intensive institutions offering data science is however insufficient, and there is a desperate need for more training in data science. The CODATA-RDA Schools of Research Data Science aim at addressing the continental need for foundational data skills across all disciplines, along with training conducted by The Carpentries[9] programme (specifically Data Carpentry[10]). Thus far, CODATA-RDA schools in collaboration with AOSP, integrating content from Data Carpentry, were presented in Rwanda (in 2018), and during17-29 June 2019, in Ethiopia.

Awareness regarding Open Science (including Open Data) is evident through the 12 Open Science-related Open Access/Open Data/Open Science declarations and agreements endorsed or signed by African governments; 200 Open Access journals from Africa registered on the Directory of Open Access Journals (DOAJ); 174 Open Access institutional research repositories registered on openDOAR (Directory of Open Access Repositories); 33 Open Access/Open Science policies registered on ROARMAP (Registry of Open Access Repository Mandates and Policies); 24 data repositories registered with the Registry of Data Repositories (re3data.org) (although the pilot project identified 66 research data repositories); and one data repository assigned the CoreTrustSeal. Although this is a start, far more needs to be done to align African data curation and research practices with global standards.

Funding to conduct research remains a challenge. African researchers mostly fund their own research, and there are little incentives for them to make their research and accompanying data sets openly accessible. Funding and peer recognition, along with

[7] https://www.skatelescope.org/
[8] https://repository.ubuntunet.net/bitstream/handle/10.20374/69/NREN_Capability_Maturity_Model.pdf?sequence=1&isAllowed=y
[9] https://carpentries.org/
[10] https://datacarpentry.org/

an enabling research environment conducive for research, are regarded as major incentives.

The landscape report concludes with a number of concerns towards sharing research data openly, as well as challenges in terms of Open Data policy, ICT infrastructure supportive of data sharing, capacity building, lack of skills, and the need for incentives. Although great progress has been made in terms of Open Science and Open Data practices, more awareness needs to be created and further advocacy efforts are required for buy-in from African governments. A federated African Open Science Platform (AOSP) will not only encourage more collaboration among researchers in addressing the SDGs, but it will also benefit the many stakeholders identified as part of the pilot phase.

The time is now, for governments in Africa, to acknowledge the important role of science in general, but specifically Open Science and Open Data, through developing and aligning the relevant policies, investing in an ICT infrastructure conducive for data sharing through committing funding to making NRENs financially sustainable, incentivising open research practices by scientists, and creating opportunities for more scientists and stakeholders across all disciplines to be trained in data management.

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

TABLE OF CONTENTS

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

LIST OF FIGURES

LIST OF TABLES

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

LIST OF ACRONYMS

4IR	Fourth Industrial Revolution
AARSE	African Association of Remote Sensing of the Environment
AAS	African Academy of Sciences
AAU	Association of African Universities
ACE	Africa Centers of Excellence
ACMA	African Coastal Marine Atlas
ACP	African Caribbean Pacific
AEC	African Economic Community
AfDB	African Development Bank
AfLIA	African Library and Information Associations & Institutions
AFReMaS	African Register of Marine Species
AfricaOSH	Open Science and Hardware in Africa
AfriGEOSS	African Group on Earth Observations
AFRISTAT	Economic and Statistical Observatory of Sub-Saharan Africa
AHRI	Africa Health Research Institute
AI	Artificial Intelligence
AIDI	Africa Infrastructure Development Index
AIH	African Information Highway
AIMS	African Institute for Mathematical Sciences
AJOL	African Journals Online
AMMA-CATCH	African Monsoon Multidisciplinary Analysis – Coupling the Tropical Atmosphere and the Hydrological Cycle
ANDI	African Network for Drugs and Diagnostics Innovation
AOSP	African Open Science Platform
AOSTI	African Observatory of Science and Technology Indicators
APHE	African Partnership for Higher Education
APHRC	African Population and Health Research Centre
ARIPO	African Regional Intellectual Property Organization
ARUA	African Research Universities Alliance
ASAL K-Hub	Arid and Semi-Arid Lands Knowledge Hub Platform
ASREN	Arab States Research and Education Network
ASSAf	Academy of Science of South Africa
ASTII	African Science, Technology and Innovation Indicators
AU	African Union
AUC	African Union of Conservationists
BITRI	Botswana Institute for Technology Research and Innovation
BIUST	Botswana International University of Science and Technology
BODATSA	Botanical Database of Southern Africa
CEMAC	Central African Economic and Monetary Community
CERSGIS	Centre for Remote Sensing and Geographic Information Systems

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

CESSDA	Consortium of European Social Science Data Archives
CGIAR	Consortium of International Agricultural Research Centers
CHPC	Centre for High Performance Computing
CIRAD	Agricultural Research for Development
COAR	Confederation of Open Access Repositories
CODATA	Committee on Data for Science and Technology
CODESRIA	Council for the Development of Social Science Research in Africa
COMESA	Common Market for Eastern and Southern Africa
CoPs	Communities of Practice
CPD	Continuing Professional Development
CPI	Corruption Perceptions Index
CSI	Consortium for Spatial Information
D4D	Digital4Development
DANS	Data Archving and Networked Services
DATAD-R	Database of Theses, Dissertations and Research Articles
DEVCO	Directorate-General for International Cooperation and Development
DG CONNECT	Directorate-General for Communications Networks, Content and Technology (European Commission)
DG DEVCO	Directorate-General for International Cooperation and Development (European Commission)
DICAMES	Digital archive of the African and Malagasy Council for Higher Education
DIRISA	Data Intensive Research Initiative of South Africa
DL	Deep Learning
dLAB	Data Science and Engineering Laboratory
DMP	Data Management Planning
DOAJ	Directory of Open Access Journals
DOI	Digital Object Identifier
DST	Dept. of Science and Technology
EAC	East African Community
EC	European Commission
ECA	Economic Commission for Africa
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
EDF	European Development Fund
EDSA	Explore Data Science Academy
eI4Africa	e-Infrastructures for Africa
EIFL	Electronic Information for Libraries
EOSC	European Open Science Cloud
EU	European Union
EUN	Egyptian Universities Network

FAIR	Data that is **F**indable, **A**ccessible, **I**nteroperable and **R**e-usable
FAO	Food and Agriculture Organization
FARA	Forum for Agricultural Research in Africa
FOSS	Free and Open Source Software
FOSTER Plus	Fostering the practical implementation of Open Science in Horizon 2020 and beyond
GAEC	Ghana Atomic Energy Commission
GAFTA	Greater Arab Free Trade Area
GBIF	Global Biodiversity Information Facility
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GGKP	Green Growth Knowledge Platform
GHDx	Global Health Data Exchange
GLOSS	Global Sea Level Observing System
GODAN	Global Open Data for Agriculture and Nutrition
GRC	Governance, Risk Management and Compliance
GSSTI	Ghana Space Science & Technology Institute
H3Africa	Human Heredity & Health in Africa
H3ABioNet	Human Heredity & Health in Africa Bioinformatics Network
HDI	Human Development Index
HE	Higher Education
HIPSSA	Harmonization of ICT Policies in sub-Saharan Africa
HoA-REC&N	Horn of Africa Regional Environment Centre and Network
HPC	High Performance Computing
IAP	InterAcademy Partnership
IAU	International Astronomical Union
iCEOD	ICT Centre of Excellence & Open Data
ICRAF	World Agroforestry Centre
ICT	Information and Communication Technologies
IDiA	Inter-University Institute for Data Intensive Astronomy
IDRC	International Development Research Centre
IGAD	Intergovernmental Authority on Development
IFLA	International Federation of Library Associations and Institutions
IIS	Institute for Intelligent Systems
INDEPTH	International Network for the Demographic Evaluation of Populations and Their Health
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data and Information Exchange
IOGA	Institut et Observatoire de Géophysique Antananarivo
IP	Intellectual Property
IPR	Intellectual Property Rights
IR	Institutional Repository

ISC	International Science Council
ISC ROA	International Science Council Regional Office for Africa
ISPs	Internet Service Providers
ITCoEICT	India-Tanzania Centre of Excellency in ICT
IUCEA	Inter-University Council for East Africa
IXPs	Internet Exchange Points
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KAiNeT	Kenya Agricultural Information Resource Centre
KALRO	Kenya Agricultural & Livestock Research Organization
KENET	Kenya Education Network
LEDCs	Less/Least Economically Developed Countries
MalariaGen	Malaria Genomic Epidemiology Network
MASDAP	Malawi Spatial Data Platform
MDGs	Millennium Development Goals
MIPAR	Medical Image Processor and Repository
ML	Machine Learning
MOOC	Massive Open Online Course
NARSS	National Authority for Remote Sensing & Space Sciences
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASAC	Network of African Science Academies
NEPAD	New Partnership for Africa's Development
NGI	National Geo-Spatial Information
NGO	Non-Governmental Organisation
NGP	National Geomatics Plan
NICIS	National Integrated Cyberinfrastructure System
NREN	National Research and Education Network
NRF	National Research Foundation
NRO	National Roaming Operators
NSTF	National Science and Technology Forum
OA	Open Access
OAD	Office of Astronomy for Development
OAPI	Organisation Africaine de la Propriété Intellectuelle/ African Intellectual Property Organization
OBIS	Ocean Biogeographic Information System
ODI	Open Data Institute
ODINAFRICA	Ocean Data and Information Network for Africa
ODOS	Open Data and Open Science Forum
OECD	Organisation for Economic Co-operation and Development
OGP	Open Government Partnership
OHADA	Organisation for the Harmonization of Corporate Law in Africa
Open AIR	Open African Innovation Research

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

openDOAR	Open Directory of Open Access Repositories
OPEX	Operational Expenditure
PAIPO	Pan African Intellectual Property Organization
PAP	Pan-African Parliament
PASTD	Preservation of and Access to Scientific and Technical Data in/for/with Developing Countries
PAU	Pan-African University
PAUGHSS	Pan African University, Institute Of Governance, Humanities And Social Science
PAULESI	Pan African University Life And Earth Sciences Institute
PAUSTI	Pan-African University Institute for Basic Sciences, Technology and Innovation
PAUWES	Pan-African University Institute of Water and Energy Sciences
PHG	Public Health Gateway
PIDA	Programme for Infrastructure Development in Africa
POPIA	Protection of Personal Information Act
PVC	Pro-Vice-Chancellor
R&D	Research and Development
RCMRD	Regional Centre for Mapping of Resources for Development
RCR	Responsible Conduct of Research
RDA	Research Data Alliance
RDM	Research Data Management
ReBioMa	Reseau de la Biodiversité de Madagascar
REN	Research and Education Network
RENU	Research and Education Network of Zambia
RIDMP	Regional Infrastructure Development Master Plan
RISDP	Revised Regional Indicative Strategic Development Plan
ROA	Regional Office for Africa
ROARMAP	Registry of Open Access Repository Mandates and Policies
RTDI	Research, Technological Development and Innovation
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
SACU	Southern African Customs Union
SADC	Southern African Development Community
SADiLaR	South African Centre for Digital Language Resources
SADIRC	South African Data-Intensive Research Cloud
SAEON	South African Environmental Observation Network
SAIAB	South African Institute for Aquatic Biodiversity
SANBI	South African National Biodiversity Institute
SANReN	South African National Research Network
SANSA	South African National Space Agency
SARIMA	Southern African Research and Innovation Management Association
SARUA	Southern African Regional Universities Association

SASDI	South African Department of Rural Development and Land Reform Spatial Data Infrastructure
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SAWS	South African Weather Service
SciELO	Scientific Electronic Library Online
SDGs	Sustainable Development Goals
SET	Science, Engineering and Technology
SGCI	Science Granting Council Initiative
SHaSA	Strategy for the Harmonisation of Statistics in Africa
SKA	Square Kilometre Array
SLA	Service Level Agreement
SOHA	Open Science in Haiti and Francophone Africa
SPARC Africa	Scholarly Publishing and Academic Resources Coalition Africa
STATAFRIC	Pan-African Institute for Statistics
StatCom-Africa	Statistical Commission for Africa
STI	Science, Technology and Innovation
STISA-2024	Science, Technology and Innovation Strategy for Africa 2024
Telcos	Telephone Companies
TENET	Tertiary Education and Research Network of South Africa
TTA	Technology Transfer Alliance
TWAS	The World Academy of Sciences
UB	University of Botswana
UCT	University of Cape Town
UEMOA	West African Economic and Monetary Union/ Union Economique et Monétaire Ouest Africaine
UK	United Kingdom
UMA	Arab Maghreb Union
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNU	United Nations University
URL	Uniform Resource Locator
VVV	Volume Variety Velocity
WACREN	West and Central African Research and Education Network
WARIMA	West African Research and Innovation Management Association
WASCAL	West Africa Science Service Centre on Climate Change and Adapted Land Use
WATRA	West Africa Telecommunication Regulatory Assembly
WDS	World Data System
WHO	World Health Organisation
WIPO	World Intellectual Property Organisation
ZAMREN	Zambia Research and Education Network

1. INTRODUCTION: THE AFRICAN OPEN SCIENCE PLATFORM AND THE LANDSCAPE STUDY

The rationale for the African Open Science Platform (AOSP), its purpose and proposed structure and governance was set out in the draft strategy Science for the Future and the Future of Science[11] published in December 2018. The mission of the Pan-African Platform is to put African scientists at the cutting edge of contemporary, data-intensive science as a fundamental resource for a modern society.

Its building blocks are:

- a secure federated hardware, communications and software infrastructure, including policies and enabling practices to support Open Science in the digital era;
- a network of excellence in Open Science that supports scientists and other societal actors in accumulating and using modern data resources to maximise scientific, social and economic benefit.

These objectives are planned to be realised through six related strands of activity:

Strand 1: A secure federated network of computational facilities and services.
Strand 2: Software tools and advice on policies and practices of research data management.
Strand 3: A Data Science and AI (Artificial Intelligence) Institute at the cutting edge of data analytics.
Strand 4: Priority application programmes: e.g. cities, diseases, biosphere, and agriculture.
Strand 5: A Network for Education and Skills in data and information.
Strand 6: A Network for Open Science Access and Dialogue.

The following landscape study is designed to map the current landscape of principles, projects and research initiatives in the Pan-African region that are relevant to the development of the Platform. It has been undertaken by the Academy of Science of South Africa (ASSAf). Its objective is to summarise the current pattern of activitiies in Africa as a basis for planning the operational phase of the Platform, and the potential for collaboration in creating capabilities to maximise its contribution to the development of African science, in responding to the opportunities and challenges of the digital revolution.

The landscape study is an overview of Open Science (and specifically Open Data) projects, activities and initiatives that are currently underway on the continent and which have the potential to contribute to and benefit from the Platform. It reviews:

[11] https://doi.org/10.5281/zenodo.2222418

- policies, infrastructures, role-players, incentives, capacity building and skills development;
- the current state of Open Access (OA) efforts and institutional OA repositories;
- the current support for data stewardship, FAIR data management (data being **F**indable, **A**ccessible, **I**nteroperable and **R**e-usable) and data repositories;
- reference to advocacy efforts such as International Open Data Day, International Open Data Week, SOHA (Open Science in Haiti and Francophone Africa) and GODAN (Global Open Data for Agriculture and Nutrition);
- the need for more advocacy, skills development, infrastructure support, policy development, and establishing centralised communication and collaboration networks among role-players;
- national, international and regional data-intensive projects relating to both government and scientific data; and
- where data are collected from the continent and taken up into international data portals, due to Africa – in selected instances – lacking an enabling environment, to manage data within a trusted environment.

Where possible, data are presented with visual representations for easy interpretation. Repositories that are hosting publicly accessible data sets related to the SDGs are presented in table format as Appendix 1. Where possible, a distinction was made between *research data*[12] and *government data*[13]. The latter can and are utilised for research purposes. Furthermore, government data support decisions by government towards data-driven policies (for example in Egypt and South Africa), and government data often inform and guide research across extended disciplines.

The pilot project has conducted two online surveys and has gathered information through a variety of other methods. The results form the information gathering is represented in the remainder of this landscape report. The survey targeted individuals working in data-intensive scientific domains, incl. system architects, system support staff, user support staff, data engineers, data architects, data stewards and data scientists. Individuals identified during many science events and through desk research and established networks were invited to join the African Open Science Platform mailing list[14]. Calls to complete the surveys were submitted through this mailing list. The survey was open to all members of the mailing list, and participation was voluntarily. The first survey was completed by 30 respondents, and the second survey by 72 respondents. There are currently 1,442 members registered on the mailing list.

[12] "Research data are defined as recorded factual material commonly retained by and accepted in the scientific community as necessary to validate research findings; although the majority of such data are created in digital format, all research data are included irrespective of the format in which it is created." (Engineering and Physical Sciences Research Council, 2019)
[13] 'Government data' refers to data "produced or commissioned by government or government-controlled entities." (Open Definition, n.d.)
[14] https://groups.google.com/d/forum/african-open-science-platform

2. SURVEY FINDINGS

The response rate to both the initial and second surveys were relatively low (the first survey had a response of 2.1% and the second survey 5%), which might have been a reflection of the relative lack of established Open Data initiatives, limited awareness of research data, lack of Pan-African programmes and organisations, and the typical low rates of questionnaire reponse where the benefits of responding are not apparent. It may also reflect the relatively low levels of organisation and funding of many science systems in Africa (2018 Sustainable Development Report: United Nations Economic Commission for Africa[15]). Most African countries have not or are not able to make the levels of investment in science, technology and innovation that are needed for economic transformation, which directly impact on their Human Development Index (United Nations Human Development Report 2018[16]). Kenya and South Africa are ranked highest with 0.8% of its gross domestic product (GDP) invested in research and development (R&D), which is the closest to the AU's (African Union's) suggested 1%. Countries such as Lesotho and Madagascar ranked as 0%, while the R&D expenditure for 24 African countries is unknown.

The first survey examined the activities that make up the research data lifecycle, including: policy development, ethics, data curation (including planning, management, and preservation), data collection, data sharing, and publishing of research results, with a particular focus on data sets collected to address research that addresses the SDGs, including both *open government data* and *open research data*. Data initiatives were limited to initiatives for which the information is openly accessible (no login required to access the information), or partially open (free registration a requirement to access information).

The second survey covered four areas: Open Data policy development, incentives, capacity building, and infrastructure. The survey results informed the following:

- **Policy Development:** What policy frameworks are required to help take advantage of the data revolution and Open Data? What elements should be addressed when developing an Open Data policy?
- **Incentives:** What are the benefits of Open Data for African research institutions, researchers and research groups? What are the disincentives for data sharing? How can these be mitigated?
- **Data Skills and Training:** What are the foundational data skills we need to develop? How can data training be achieved at scale? Can we use the approaches of Data Carpentry, Software Carpentry and the CODATA-RDA School of Research Data Science? What other initiatives can we learn from?
- **Data Infrastructure Roadmap:** What are the priorities in terms of infrastructure? How can we ensure data infrastructure benefits African

[15] https://www.uneca.org/publications/2018-africa-sustainable-development-report
[16] http://hdr.undp.org/en/2018-update

researchers and research institutions? How can we build on existing work in South Africa and SADC?

Following are selected findings from the surveys.

2.1 ROLE-PLAYERS

An important objective of the landscape study was to understand the pattern of data-intensive activities. The first survey identified 30 projects – in different phases of development – that can be categorised into four broad categories. These are:

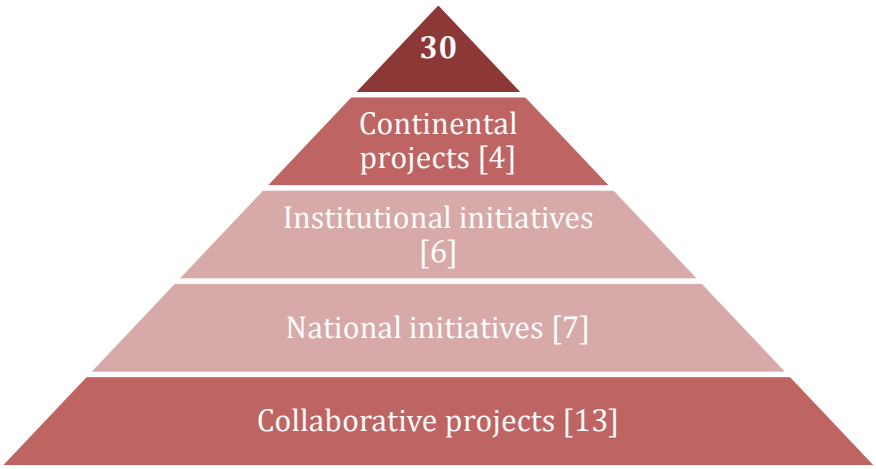


Figure 1. Broad categories of data-intensive projects in Africa

- **Continental projects** – Projects that are not focused on any specific region but encompass the wider scope of Africa, such as the Database of African Theses and Dissertations and Research (DATAD-R [17], Association of African Universities), and the Ocean Data and Information Network for Africa (ODINAfrica)[18] (Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organisation (UNESCO)). Two of the listed projects have a distinct Pan-African focus – Rainfall data inter-comparison tool[19] (University of Reading, United Kingdom (UK), and Global Biodiversity Information Facility (GBIF)-Africa[20], with the current regional node representative based at the South African National Biodiversity Institute (SANBI)[21].

- **Institutional initiatives** related to the higher education sector with a focus on institutional research management systems and training programmes.

[17] http://datad.aau.org/
[18] http://www.odinafrica.org/
[19] https://research.reading.ac.uk/meteorology/atmospheric-observatory/atmospheric-observatory-data/
[20] https://www.gbif.org/the-gbif-network/africa
[21] https://www.sanbi.org/

- **National initiatives** – A large proportion of data initiatives at the national level are related to government data, including projects such as the Bureau of Statistics, Lesotho (survey data for public access and international comparison); Institute for Meteorological Training and Research, Kenya (climatological applications and environmental analysis); and Ministry of Environment, Ecology and Forest, Madagascar (environmental data, biodiversity data, protected areas and disaster management).

- **Collaborative projects** – The largest category encompasses a number of collaborative projects that can be discipline, regional or service delivery specific.

2.2 DATA ACTIVITY

Responses indicated that more than 50% of the respondents who completed the survey engage in initiatives related to Open Data policies, data repositories and stewardship, skills training, data standards and data analysis systems. The following fugure shows responses to a request for respondents to declare the range of activities in which they are involved:

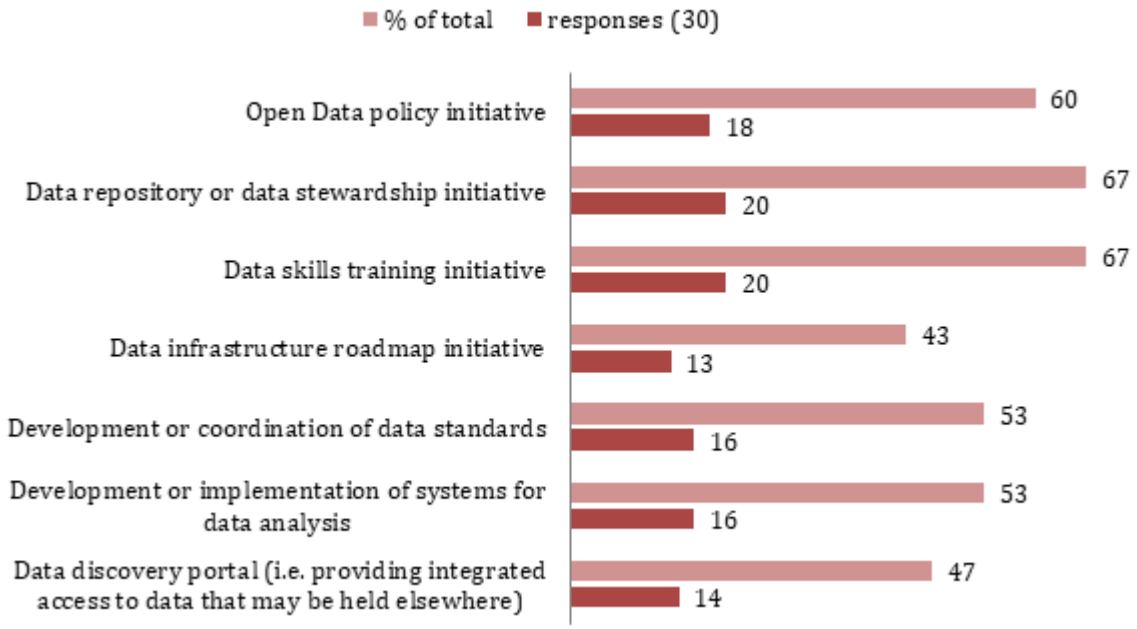


Figure 2. Responses to survey question on "Which of the following applies to the Data Activity?"

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

2.3 PROJECTS

Responses about projects[22] reported a diversity of discipline-specific projects, but also extended to skills development programmes and capacity building – ❻, policy development – ❶, infrastructure support – ❷, and data visualisation services – ❷.

The discipline specific projects identified in the following table below show the number of projects related to specific fields of:

Institutional data management in the higher education arena –❽	Environmental studies (including meteorology, oceanography & land-cover and land-use) – ❹
Biodiversity – ❸	National resource development, governmental survey data & mapping initiatives – ❸
Humanities and social sciences (including digital humanities) – ❸	Satellite imagery – ❷
Health sciences – ❶	Disaster management – ❶

Table 1. Specific fields of projects identified by the survey

2.4 FUNDING

The following diagram summarises the different streams of funding used for current and prospective projects:

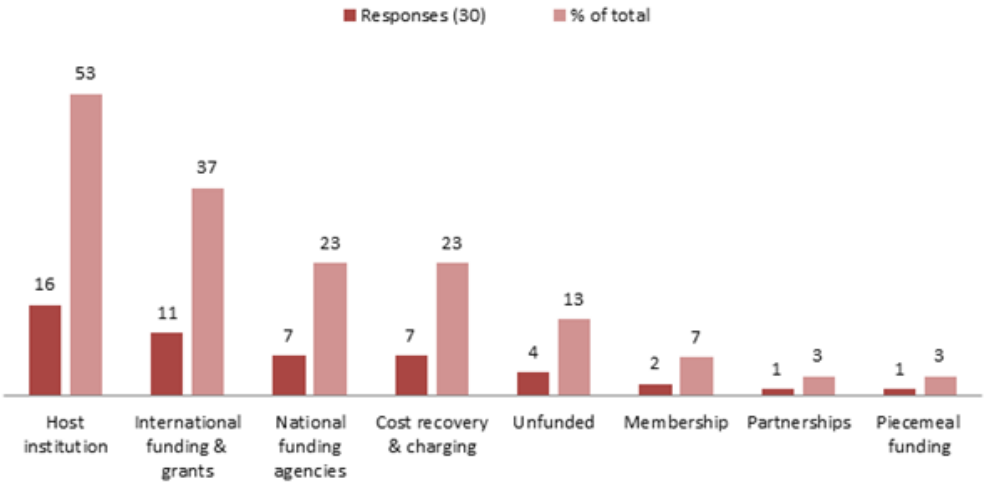


Figure 3. Survey responses to funding through different streams

[22] Seven projects were listed at the time of the survey as in progress: Research data repositories by the Bindura University of Science Education, Nigeria, the University of Botswana, University of Pretoria (South Africa), University of the Western Cape (South Africa); data mapping app initiative by Ground Aspects; *Gestion Nationale des Informations Environnementales et Spatiales* (GENIES)-platform in Madagascar; data analysis services by the National University of Science and Technology, Zimbabwe.

The development and sustainability of these projects are reliant on a number of role-players – often combined – such as international and national funding, with the host institution supporting operational activities, such as hardware and maintenance. In addition to the information presented in the chart, respondents also indicated that projects are funded through contributions by member countries, bilateral agreements and collaborative projects, with some utilising self-funded product development from commercial service activities (such as cost recovery or charging).

2.5 ADVANCING OPEN SCIENCE

When asked what needs to be done to advance Open Science in the second survey, the majority of participants indicated that there is a huge need for advocacy and awareness creation among all stakeholders – librarians, researchers, policy and decision-makers and students. Advocacy includes awareness creation of the benefits offered by Open Science and data sharing through different fora, as well as the need for more collaboration and sharing of resources. Respondents indicated that policy should make provision for securing sensitive data, commercialisation prospects and patents as a result of research, addressing concerns regarding security and Intellectual Property Rights (IPR), acknowledging researchers through institutional recognition systems (metrics) and training in terms of curating and sharing quality data.

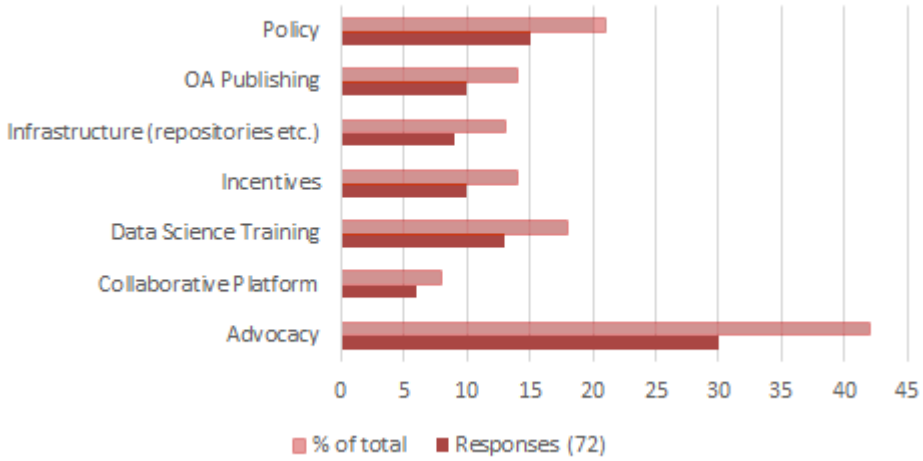


Figure 4. Survey responses to "What can be done to promote Open Science?"

2.6 BARRIERS TO OPEN SCIENCE

Traditional cultures that exist within institutions and among researchers conducting science are major barriers to practicing Open Science. 43% (31 respondents) indicated that historical cultures keep them from exploring new ways of doing science. Publishing in high impact journals is still widely used for performance appraisal. Researchers prefer to work in silos because of fears e.g. of being scooped, "exposed", funding their own

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

research and not benefitting, and the lack of incentives including an enabling environment. The lack of Open Science supportive policies make researchers uncertain as to which practices to apply when conducting science, and whether they will be able to rely on institutional support when data is being questioned.

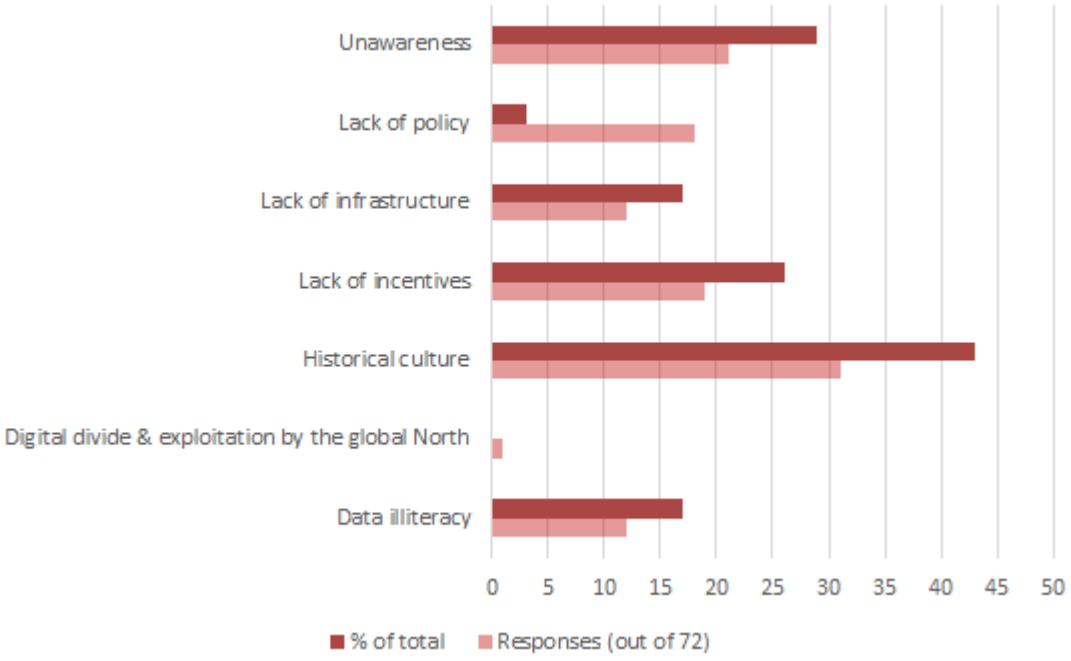


Figure 5. Survey responses to barriers preventing Open Science practices

3. AOSP PILOT RESEARCH INTO THE AFRICAN OPEN SCIENCE LANDSCAPE

The pilot team has pursued a number of means to gather information to augment the information collected through the two online surveys. These means included:

- Desk research: Conducting secondary research and verifying information
- Establishing a community of practice by developing a connective communication platform for sharing information related to Open Science, among 1 500+ members
- Networking with relevant stakeholders
- Signing of 7 Service Level Agreements (SLAs) and 4 Agreements for consultative work
- Developing a registry of data-intensive initiatives and scientists, containing 1 500+ entries
- Identifying a contact person in Ministries of Science and Technology in 22 countries

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

- Participation in 44 conferences to further contribute to advocacy for Open Science and creating awareness for the African Open Science Platform and supporting the branding of the initiative
- Case study presentations by different countries
- Presenting 15 workshops and 5 virtual presentations on Open Science and Open Data
- Co-hosting and supporting participation in an international conference on Open Data (International Data Week, 2018)[23]

The pilot project identified many data-intensive science-related activities on the continent (though they are not always visible, accessible and/or well managed), especially where there is funding (both national and international), buy-in from government, and political willingness to invest in science, technology and innovation. Much is to be gained for all if there were greater coordination of activity. However, registration of Open Science – and specifically Open Data – activities on monitoring systems is cumbersome for African countries and cannot be used for the purposes of identifying the broader scope of data activities on the continent.

3.1 POLITICAL WILLINGNESS

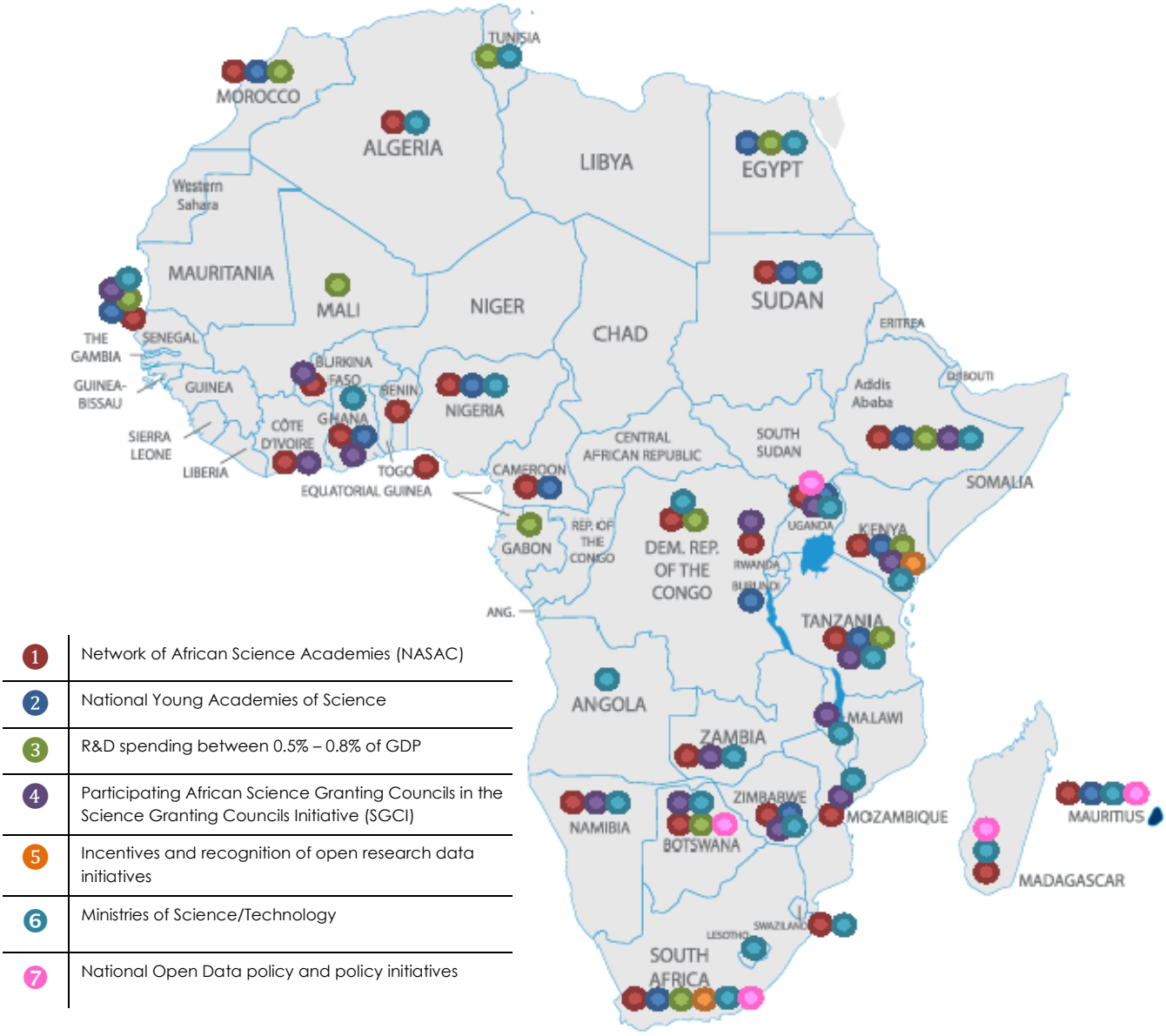
The project gathered information to assess political willingness to invest in ICT, R&D, openness and policy. This is presented in a map below with the following inputs:

- Ministries of Science and Technology and the Research and Development spending in terms of the GDP;
- National Open Data policy and policy initiatives;
- Incentives and recognition of science research data initiatives;
- Participating African Science Granting Councils in the Science Granting Councils Initiative (SGCI);
- Membership of the Network of African Science Academies (NASAC); and
- National Young Academies of Science.

This allowed identification of possible key stakeholders for participation and development of the AOSP as well as developing a registry of roleplayers.

[23] http://www.internationaldataweek.org/about-idw-2018-0

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047



1	Network of African Science Academies (NASAC)
2	National Young Academies of Science
3	R&D spending between 0.5% – 0.8% of GDP
4	Participating African Science Granting Councils in the Science Granting Councils Initiative (SGCI)
5	Incentives and recognition of open research data initiatives
6	Ministries of Science/Technology
7	National Open Data policy and policy initiatives

Figure 6. Map of political willingness on the African continent

3.2 STAKEHOLDER CONSULTATION

The AOSP built on existing initiatives (such as SOHA (Open Science in Haiti and Francophone Africa)[24], GODAN (Global Open Data for Agriculture and Nutrition)[25] and Open AIR (Open African Innovation Research)[26] on the continent – some still active, while others have come to an end – to create more awareness of the need for Open Data, and

[24] https://ocsdnet.org/tag/soha-project/
[25] https://www.godan.info/
[26] http://www.openair.org.za/

to advocate for a future AOSP. Opportunities such as the International Open Data Day[27], International Data Week[28], and Open Access Week[29] were further utilised to build momentum.

The stakeholder consultation included both national entities (e.g. ministries of science, ICTs or environment, national councils for science and technology, participants in the SGCI, data gathering initiatives and universities) and Pan-African or regional bodies (e.g. the African Academy of Sciences (AAS) and Network of African Science Academies (NASAC) for academies, Association of African Universities (AAU) and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for universities, WACREN (West and Central African Research and Education Network) and UbuntuNet Alliance for NRENs (National Research and Education Networks).

Stakeholder meetings with such relatively high level paricipation were organised in several African countries, including workshops designed to create cross-discipline awareness of Open Science projects and discuss shared concerns and challenges. Meetings have included participants from Botswana, Burkina Faso, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Madagascar, Morocco, Nigeria, South Africa, Tanzania, Uganda, and Zimbabwe.

The following is a list of selected stakeholders engaged during these meetings:

- African Academy of Sciences (AAS)
- African Development Bank (AfDB)
- African Governments
- African Research Councils
- African Union/NEPAD
- African Union/Pan-African Parliament (PAP)
- Association of African Universities (AAU)
- Global Network of Science Academies/ InterAcademy Partnership (IAP)
- International Science Council (ISC)
- International Science Council bodies
    - Committee on Data for Science and Technology (CODATA)
    - Regional Office for Africa (ROA)
    - World Data System (WDS)

[27] https://opendataday.org/
[28] https://internationaldataweek.org/
[29] http://www.openaccessweek.org/

- National Academy of Sciences (NAS)
- Network of African Science Academies (NASAC)
- National Research and Education Networks (NRENs)
- Research Data Alliance (RDA)
- Science Granting Council Initiative (SGCI)
- The World Academy of Sciences (TWAS)
- United Nations (UN)
- World Intellectual Property Organisation (WIPO-Africa)

Table 2. AOSP stakeholder engagement

3.3 WORKSHOPS AND MEETINGS

As part of its commitment to advance data sharing and practising Open Science on the continent, AOSP organised a series of meetings and workshops. These events were used for advocacy, to build a community of practice and to gather information about stakeholders and their current or potential engagement with AOSP and with Open Science more generally. Representatives fro 37 of 54 African countries attended these meetings (see Figure 7).

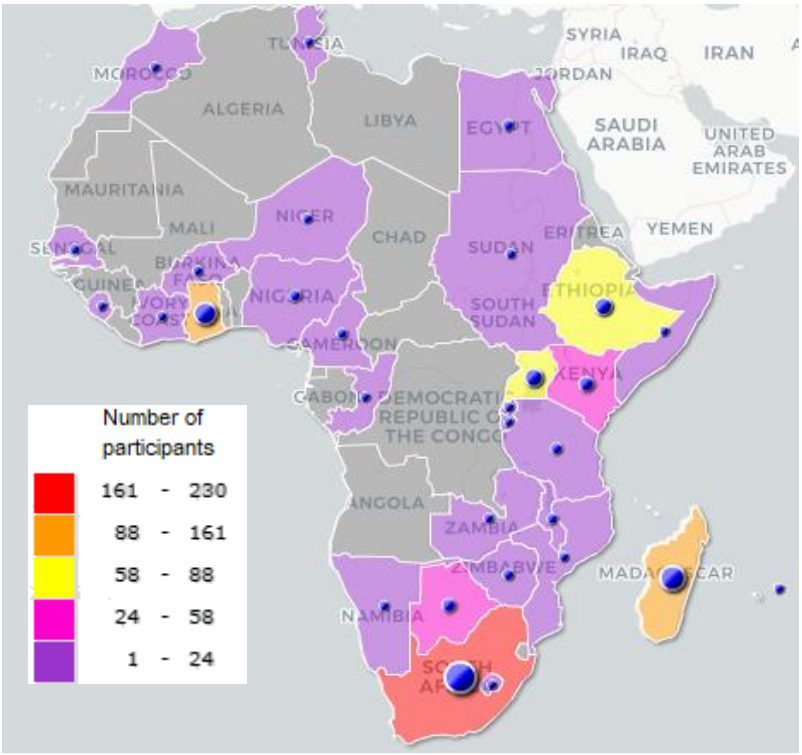


Figure 7. Map[30] of countries represented by participants and presenters, during AOSP meetings and workshops

[30] https://www.targetmap.com/viewer.aspx?reportId=61508

National Open Data fora were established in Botswana, Madagascar, and Uganda as an outcome of these meetings and workshops.

3.3.1 NATIONAL WORKSHOPS

Botswana – The first Botswana National Forum on Open Data Open Science (30-31 October 2017) was used to create awareness on Open Data and to explore the current data situation in Botswana, challenges faced in terms of Open Science (including Open Data) policy, utilising and adapting the current ICT infrastructure/fibre connections to allow for the transmission of data sets to advance science, and building capacity – not only in terms of plans to manage research data on individual researcher/project level, but also in terms of soft skills to properly manage and re-use data. Botswana does not currently have an NREN, but it is on the agenda. The forum further identified strengths, opportunities, weaknesses and threats to embracing Open Data and Open Science in Botswana.

Statistics Botswana[31] (focusing on government data) is one of the success stories from the country. The Botswana government shared their commitment to develop a knowledge economy which sees the enhancement of data skills and the development of research data infrastructures, through participating in this Forum. Doing African science the African way, but also doing Botswana science the Botswana way – steering away from benchmarking with countries they have very little in common with, at the same time implementing international best practice, was an excellent message to take away from this meeting. The Botswana ODOS (Open Data Open Science) National Committee drives the Open Science Open Data initiative, and the Draft White Paper on Open Research Data Strategy is a major outcome of the work done by ODOS. The University of Botswana (UB), Botswana International University of Science and Technology (BIUST) and the Botswana Institute for Technology Research and Innovation (BITRI) are strongly engaged in the process. A further major investment in Open Data was made by the Botswana Minister of Tertiary Education, Research, Science and Technology, hosting International Data Week (IDW)[32] from 5-8 November 2018. The AOSP was a co-organiser to this event, along with CODATA, WDS (World Data System), UB and the RDA. AOSP further funded participation of selected Africans in this milestone event. IDW2018 created the opportunity for data experts from Botswana and from Africa to actively share and engage with colleagues across the globe, networking, and finding opportunities for future collaboration.

Madagascar[33] - A High-Level Meeting on Environmental and Scientific Open Data for Sustainable Development Goals in Developing Countries (4 September 2017) was convened by the African Open Science Platform Project, CODATA and the CODATA PASTD Task Group, between the Madagascar Ministry of Environment, Ecology and Forest; Ministry of Post, Telecommunication and Digital Development; Ministry of Higher Education

[31] http://www.statsbots.org.bw/
[32] https://www.internationaldataweek.org/
[33] Madagascar Report from a High-Level Meeting on Environmental & Scientific Data for Sustainable Development Goals in Developing Countries https://drive.google.com/open?id=1eRi-Q-S3RUiBSDzYDGHEOKNoNXiWWmsD

and Research, and the Ministry of Economy and Planification. This was followed by a two-day workshop (5-6 September 2017) with organisational stakeholders from Madagascar. The objectives of the meetings included the promotion of strategy, policy and institutional guidelines for implementation of Open Data principles; providing an interdisciplinary forum for enhancing capacity building and sharing best practice; advancing data publishing; and enhancing data re-use and repositories in support of sustainable development in Madagascar.

A national data roadmap is in development in Madagascar but it is primarily concerned with government data. Although there is real concern about research data being protected, and an interest in data science and a need for data infrastrucutre among a number of research and monitoring sectors, particularly those relating to SDGs and the environment/ biodiversity, there are major resource issues. Madagasar however has a strong NREN that is engaged with providing the necessary infrastructure in support of research and education, which is an important driver towards implementing Open Data.

During the closing of the two day workshop, the Secretary General of the Ministry of Environment, Ecology and Forest underlined that the process for drafting the Open Data policy can be started. A governmental strategy was also tabled for evaluating country capacity. On behalf of the Madagascar Government, he expressed the Malagasy readiness for being involved in the Open Data process. He concluded by saying that Madagascar will strive for findings on environmental issues to be widely published and opened on national and international level.

Uganda[34] – The Uganda National Dialogue on Open Science and Open Data (25–27 April 2018) was convened in partnership with the African Union of Conservationists. The workshop focused on Uganda's draft Open Data Policy, discussing research data issues, including strategy, stakeholders, barriers, incentives, policies, technical infrastructure and training. The workshop further reflected on projects on Open Data, subject repositories, visualisations and the much needed cyber infrastructure for Uganda.

Stakeholders in Uganda recognised the need to enhance data infrastructure for research and monitoring in relation to SDGs, particularly applicable to cities and biodiversity. From meetings with the Vice Chancellor and PVC Research, it was clear that the Makerere University has a major interest in enhancing its data capacity. The Makerere University further hosts RUFORUM, which has already been involved in AOSP on behalf of agricultural universities. The Uganda National Council for Science & Technology has further expressed considerable interest in the issues discussed.

South Africa – Although not under the AOSP umbrella, the South African Department of Science and Technology (DST) has – in partnership with the European Union (EU) – started a dialogue on an Open Science policy framework for the country in 2016. This formed part

[34] Report from the Uganda National Dialogue on Open Science and Open Data https://drive.google.com/open?id=1IvNMDmobnT2U0f72bb6JIVcPfs-v7N_Q

of a broader SA-EU Strategic Partnership Dialogue Facility[35]. The SA-EU Open Science Dialogue Report[36] was released during the annual SFSA[37] (Science Forum South Africa) in 2018. The 2019-released South African White Paper on Science, Technology and Innovation [38] further confirms South Africa's commitment as part of African STI cooperation, to help advance the Open Science agenda elsewhere on the continent and within regional frameworks. It further acknowledges "[T]the strategic role of the African Open Science Platform, hosted by the Academy of Science of South Africa[39], which promotes African-wide development and coordination of data policies, data training and data infrastructure, [which] will be leveraged with the support of the DST and the National Research Foundation (NRF). In addition, South Africa is one of the founding members of the global Open Government Partnership[40], and took over the chair in 2015. As one of the signatories of this partnership, South Africa is committed to developing an Open Data policy framework and action plan."

3.3.2 STAKEHOLDER WORKSHOPS

Given the interest in FAIR data and Open Science capacity, workshops in collaboration with the AAU (Associaion of African Universities) and the NRENs (National Research Education Networks) were further vital in taking AOSP forward.

AOSP/RDA Open Science Workshop – An AOSP/RDA workshop on Open Science/Open Data policy was presented as part of the 14th General Conference of the Association of African Universities (AAU), 5-8 June 2017, Accra, Ghana. A number of countries presented case studies based on their national and or institutional Open Data progress. These case studies informed the landscaping of Open Data initiatives on the African continent, due to its first-hand comprehensive description of the *status quo* in the respective countries. Case studies presented were from Botswana, Burkina Faso, Cameroon, Kenya, Madagascar, Namibia, Nigeria and Senegal. Information collected on progress or lack thereof, has been incorporated as part of Section 4 of this document.

AOSP/UbuntuNet Alliance Workshop – The African Open Science Platform partnered with the organisers of the UbuntuNetConnect 2017 Conference and hosted a pre-conference workshop on 1 November 2017, in Addis Ababa, Ethiopia – focusing on data infrastructure and capacity building – to 65 participants from all over Africa. National Research Education Networks (NRENs) are key to science conducted by research intensive institutions, providing a highly trusted and affordable lifeline not only in terms of connectivity/bandwidth and selected services, but also in providing an enabling environment conducive for research data sharing, data stewardship and high level compute.

[35] https://www.dialoguefacility.org/
[36] https://drive.google.com/file/d/1H5CAxtkMzj-IpLQf46wGhvTNE4zmS9D9/view?usp=sharing
[37] http://africanopenscience.org.za/?p=1104
[38] https://www.dst.gov.za/images/2019/FINAL-White-Paper-to-Cabinet_11-March-2019.pdf
[39] https://www.assaf.org.za/
[40] https://www.opengovpartnership.org/

Prof Afework Kassu (State Minister for Science and Technology, Ethiopia) during his opening made the comment that openness should be embraced towards global peace. He further said that we need to lay the foundation for future citizens. We also need universities and industries to work together to promote further innovations. The important role of digital library systems to benefit students and staff was highlighted. A Science Cloud, and Science Cafes in the city (Addis Ababa) for citizens to benefit from, are just two of the very successful initiatives. He ended by saying that Africa needs a continental strategy for Science and Technology towards addressing the objectives of the United Nations 2063 Agenda.

3.4 REGISTRY

A register of organisations and individuals working on data-intensive projects has been compiled. Contacts were sourced via desk research, email introductions by existing contacts, and networking during related events. It will be necessary for it to be updated regularly, actively developed and expanded. The registry currently consists of approximately 1,500 entries representing individuals working on different initiatives and in different African countries, related to STI, ICT, IPR and HE (higher education). The registry – for the duration of the pilot – was used to collect data to inform the landscape study, identify invitees to meetings and workshops, to connect experts with one another, and to identify speakers during various events in which AOSP participated.

3.4.1 ROLE-PLAYERS – NETWORK AND DIALOGUE

A number of national, regional, continental and international actors are involved in Science networking and dialogue, and can potentially also get involved in Open Science networking and dialogue. These include, but are not limited to the following role-players:

International initiatives & role-players

Organisations – United Nations (UNECA, UNESCO, UNU, StatCom-Africa); International Science Council (CODATA, WDS, ISC ROA); Research Data Alliance (RDA); European Commission (EOSC); GÉANT; DG DEVCO; World Intellectual Property Organisation (WIPO); TWAS (NASAC); IFLA (AfLIA); OECD; InterAcademy Partnership (IAPScience, IAPPolicy, IAPHealth); HIPSSA

Funding Agencies – World Bank; IDRC; Wellcome Trust; Robert Bosch Stiftung; GIZ; JRS Biodiversity Foundation; Global Research Council (SGCI Africa)

Continental initiatives & role-players

Organisations – African Union Regional Economic Communities (SADC (incl. SARIMA), ECOWAS (including WARIMA), AEC, ECCAS, EAC, COMESA, IGAD, CEMAC, SACU, UEMOA, UMA, GAFTA); NEPAD (including PIDA); Education,

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

Science & Technology (African Virtual E-University, Pan-African University); Pan-African Parliament; AOSTI; PAIPO; AfricaConnect (UbuntuNet Alliance, WACREN, ASREN); AfLIA; ARIPO; AfricaOSH; African Research Cloud (including SADIRC); STATAFRIC; AfricArXiv; WATRA

Funding Agencies - AfDB (including country offices); SGCI

Academies of Science – AAS; NASAC (Also refer to Section 3.4.2)

Universities – AAU; ARUA (including SARUA, EUN, IUCEA, RUFORUM); Pan-African University (AU) (including PAUSTI, PAUWES, PAULESI, PAUGHSS)

Intellectual Property Rights Organisations – PAIPO (AU); OAPI; ARIPO; WIPO (including country offices)

Discipline-specific Research Networks – **Agriculture** (CIRAD, GODAN, FARA, KALRO, CGIAR, RUFORUM, FAO); **Biodiversity** (GBIF, SANBI); **Environment** (HoA-REC&N, AARSE, SASSCAL, WASCAL, AMMA-CATCH, ICRAF); **Health** (ANDI, INDEPTH, H3Africa, H3ABioNet, AHRI, APHRC, MalariaGen); **Mathematics** (AIMS); **Astronomy** (IDiA, SKA, OAD); **Social Science** (CODESRIA); **Earth Observation** (AfriGEOSS, RCMRD, CERSGIS, NARSS); **Ocean** (GLOSS, IOC, IODE, OBIS, ODINAFRICA)

Centres of Excellence – ARUA[41] (12 centres); NRF[42] (15 centres); ACE[43] (24 centres)

National initiatives & role-players

Ministries (STI, ICT, HE, IP); Academies of Science; Universities; Institutes; Centres of Excellence; NRENs; SGCs; IP Offices (WIPO, PAIPO, OAPI, ARIPO); Research Councils; Telecommunications Regulatory Bodies

Universities – African Centre of Excellence in Data Science (University of Rwanda); African Institute for Mathematical Sciences (AIMS) Pan-African network with centres in Cameroon, Ghana, Senegal, South Africa, Tanzania, and Rwanda; Almaahad Almutagadem Specialized Computer Training Centre (Sudan); High Performance Computing, India-Tanzania Centre of Excellency in ICT (ITCoEICT) (Tanzania); Institute for Intelligent Systems (IIS) Lagos State University (Nigeria); Pan-African University (PAU, Kenya); ICT Centre of Excellence & Open Data (iCEOD) (Jomo Kenyatta University of Agriculture and Technology, Kenya); Sol Plaatje University (South Africa); University of Abomey-Calavi (Benin); University of Botswana

[41] http://arua.org.za/coe/
[42] https://www.nrf.ac.za/division/rcce/instruments/centre-of-excellence
[43] https://ace2.iucea.org/index.php/2-uncategorised/110-list-of-centers-of-excellence-aceii

(Botswana); University of Cape Town (South Africa); University of Johannesburg (South Africa); University of Pretoria (South Africa); University of the Western Cape (South Africa); and University of the Witwatersrand (South Africa)

3.4.2 ACADEMIES AS CHAMPIONS

Academies of science – through the Network of African Science Academies (NASAC) – should be invited to take leadership in respective countries. In most instances Academies of science are state funded and play an important role in science diplomacy and engagement efforts. There are 26 senior Academies of science on the African continent in the following countries:

> Algeria, Benin, Botswana, Burkina Faso, Cameroon, Democratic Republic of the Congo, Côte d'Ivoire, eSwatini (former Swaziland), Ethiopia, Ghana, Kenya, Madagascar, Mauritius, Morocco, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe

The Global Young Academy Working Group for Open Science[44] is a dynamic initiative and includes representation from Africa. They work together with key stakeholders in the Open Science movement and is actively promoting policy change towards Open Science. They further promote an inclusive approach towards Open Science, with a special focus on Open Access, Open Data, Open Source Software, with a new initiative on Open Conferences. Thus, it is important to involve the national young academies of science (15 in total in Africa) in championing Open Science and the sharing of data on the continent. These include the following countries:

> Burundi, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Mauritius, Morocco, Nigeria, Senegal, South Africa, Sudan, Tanzania, Uganda, and Zimbabwe

This specific working group has on-going collaboration with the Committee on Data of the International Council for Science (CODATA) and the Research Data Alliance (RDA), towards developing international training and policy guidelines on Open Data for their respective research disciplines.

3.4.3 FUNDING AGENCIES

International funding agencies, such as the International Development Research Centre (IDRC), Wellcome Trust, and Bill & Melinda Gates Foundation are leading the way towards requiring data collected as part of research projects to be made openly accessible. According to the Open Research Funders Group[45], this is motivated by the mission to fund research with the purpose to address the challenges faced globally.

[44] https://globalyoungacademy.net/activities/open-science/
[45] http://www.orfg.org/

In addition to global partners, continental partners, such as the Science Granting Councils Initiative (SGCI)[46] also aim to strengthen the capacities of science granting councils in sub-Saharan Africa in order to support research and evidence-based policies that will contribute to the continent's economic and social development. The SGCI participating African Science Granting Councils consist of 16 members from the following countries:

> **Botswana** – Botswana Ministry of Tertiary Education, Research, Science and Technology
> **Burkina Faso** – Fonds National de la Recherche et de l'Innovation pour le Developpement
> **Côte d'Ivoire** – Programme d'Appui Stratégique à la Recherche Scientifique
> **Ethiopia** – Ministry of Science and Technology
> **Ghana** – Ministry of Environment, Science, Technology and Innovation
> **Kenya** – National Research Fund & National Commission of Science and Technology and Innovation
> **Malawi** – National Commission for Science and Technology
> **Mozambique** – Fundo Nacional de Investigação
> **Namibia** – National Commission on Research Science and Technology
> **Rwanda** – National Council for Science and Technology
> **Senegal** – Ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation
> **South Africa** – National Research Foundation, Department of Science and Technology
> **Tanzania** – Tanzania Commission for Science and Technology
> **Uganda** – Uganda National Council for Science and Technology
> **Zambia** – National Science and Technology Council
> **Zimbabwe** – Research Council of Zimbabwe

The Global Research Council (GRC) [47] – of which the mentioned African Science Granting Councils are members - is a virtual organisation, comprised of the heads of science and engineering funding agencies from around the world, dedicated to promote the sharing of data and best practices for high-quality collaboration among funding agencies worldwide. During the 2018 SGCI Forum (Côte d'Ivoire, 2018), a Statement of Principles and Actions: Social and Economic Impact of Research (2018), was released. In this statement, it was expressed that GRC participants should support and advocate for the development and use of Open Science platforms that widen access to knowledge and allow integrated problem solving at a potentially transformative (as opposed to incremental) scale. In support of Open Science, it further states that GRC participants should commit funding towards the development of the human capital necessary for leveraging the potential of Big Data, as well as invest in the infrastructure required materialising Open Science platforms.

[46] https://sgciafrica.org/en-za
[47] https://www.globalresearchcouncil.org/about/global-research-council/

The Statement on Open Access to Research Publications from the National Research Foundation (NRF)-Funded Research (2015)[48] – in science circles incorrectly labelled as a "policy" – is the only one of its kind on the continent, also calling for the data supporting NRF-funded publications to be made publicly accessible by depositing accompanying data in a trusted repository, and making provision for Digital Object Identifiers (DOIs) for data citation purposes.

4. STATUS OF OPEN SCIENCE ACTIVITIES AND CAPACITIES IN AFRICA

The future AOSP will be an effort to align with initiatives globally, namely with the Joint Information Systems Committee (JISC, UK), National Science Foundation (NSF, US), the European Open Science Cloud (EOSC, Europe), Compute Canada (Canada) and the Australian Research Data Commons (ARDC, Australia). An understanding of what is happening on the African continent is therefore crucial towards strategising and understanding what is needed to achieve the expected outcomes, and towards alignment with the global Open Science community.

In Europe and North America, research funders have developed and introduced Open Access, Open Data and Open Science policies. Emerging research economies have also taken significant steps (such as India 2012 and 2014, China 2018, Chile 2018, and Argentina 2018) towards data policies. As mentioned, the SGCI in sub-Saharan Africa aims to strengthen the capacities of 15 science granting councils (16 including South Africa) in sub-Saharan Africa in order to support research and evidence-based policies that will contribute to economic and social development.

Beyond a few isolated instances, more advanced support for the research data lifecycle only occurs in particular data-intensive projects within institutions and externally funded programmes in specific disciplines, such as the H3ABioNet[49] bioinformatics example. H3ABioNet is funded by the NIH Common Fund Award. There is thus a significant need to provide sustainable research lifecycle support such as offered through science gateways that provide improved access to advanced Open Source analytical methods.

4.1 POLICIES

National Open Data policies are positioned within a broader regulatory framework, together with policies for intellectual property rights (IPR), research ethics policies, policies for STI, funding policies, HE policies and ICT policies. Although there are efforts towards aligning IP, ICT and Science, Technology and Innovation (STI) policies on the continent with one another and with international policies, African governments still have a long way to go. Apart from developing the relevant policies, policies need to be aligned

[48] https://www.nrf.ac.za/media-room/news/statement-open-access-research-publications-national-research-foundation-nrf-funded
[49] https://www.h3abionet.org/

towards regulatory convergence, the environment required to implement the policies needs to be conducive, and accountability needs to be built into all policies.

It will be important for AOSP to engage with African governments, ministries and research institutions, and where possible contribute to the development of policies that support FAIR research data management and Open Science. IPR to research data is something African governments are concerned to defend. An important activity for the future AOSP will therefore be to explore these issues and demonstrate that FAIR data management and Open Science are compatible with IPR, and while data are findable, accessible, interoperable and re-usable (FAIR), it does not discard the Intellectual Property Rights that apply to the data. Open licenses such as Creative Commons Licenses should be assigned to all digital data, guiding prospective users on how the data may be re-used. Policies should further be clear on how data underlying patents should be managed – especially where patentable discoveries can lead to financial benefits. In such cases, policies can for example specify that data informing a patent be protected or managed in a specific way. Data protection regulations as applied to personal information such as the European Commission's (EU) General Data Protection Regulation (GDPR) [50] has significantly increased awareness on the rights of individuals when their data enter the digital world. According to Pillay (2018) Africa has 17 counties in which data protection legislation has been adopted. The Protection of Personal Information Act (POPIA)[51] has been introduced in South Africa, and shares many principles with the EU GDPR. In addition, the African Union (AU) has adopted the AU Convention on Cyber-security and Personal Data Protection[52], which has been signed by 14 of the 54 AU members: Benin, Chad, Comoros, Congo, Ghana, Guinnea-Bissau, Mozambique, Mauritania, Rwanda, Sierra Leone, São Tomé and Príncipe, Togo, Tunisia and Zambia. The Convention was ratified by 5 African countries this far: Ghana, Guinea, Mauritius, Namibia, and Senegal.

Open government/statistical data initiatives (see Section 6) related to the SDGs have had some success on the continent, and at times it seemed as if African governments and policy makers are more interested and regard open government data as more urgent compared to research data. Government data and research data should co-exist in a world where the contribution of the one compared to the other – when it comes to the major contribution it can make to science – should not be overlooked.

Universities such as the University of Botswana, Botswana International University of Science and Technology (BIUST), and the Makerere University (Uganda) rightly regard research data as an asset and a shop window that can increase reputation and build partnerships. Policies i) to discourage helicopter research and ii) to ensure that African researchers and universities get adequate recognition and partnership opportunities where data are made available, will be important to reassure institutions and researchers benefit.

[50] https://gdpr-info.eu/
[51] http://www.justice.gov.za/inforeg/docs/InfoRegSA-POPIA-act2013-004.pdf
[52] https://au.int/en/treaties/african-union-convention-cyber-security-and-personal-data-protection

The African Science, Technology and Innovation Indicators Initiative (ASTII) [53] was launched in 2005 by NEPAD setting out the aim to (i) develop and promote the adoption of internationally compatible STI indicators; (ii) build human and institutional capacities for STI indicators and related surveys; (iii) enable African countries to participate in international programmes for STI indicators; and (iv) inform African countries on the state of STI in Africa. The African Observatory of Science and Technology Indicators (AOSTI)[54] were established in 2011 by the African Union to help African countries to build capacity for STI policy activities and initiatives. The AOSTI report on the Assessment of Scientific Production in the African Union, 2005–2010 recommended "creating open and free access publication outlets for Africa, with improved review committees" (African Union African Observatory of Science Technology and Innovation, 2014) and highlighted the challenge of high article fee requirements for publishing in citation-indexed journals and the high subscription prices to commercially available databases. It is reasonable to assume that access to research data is also covered under this report, although not explicitly referenced at the time.

To date, the status of national Open Science/Open Data policies in development on the continent is very low:

> **Botswana** – Draft White Paper on Open Research Data Strategy
> **Madagascar** – Lobbying for Open Data Policy
> **Mauritius** – Open Data Policy
> **South Africa** – White Paper on Science, Technology and Innovation
> **Uganda** – Draft Open Data Policy

Further interest to establish an initial Open Science policy dialogue platform has been expressed by Uganda and Sudan, depending on AOSP funding available as part of the next phase.

4.2 E-INFRASTRUCTURE (INCLUDING STEWARDSHIP)

Due to the rapid escalation in the importance of data, collaborative research, data sharing, the growing dependency on broadband connectivity, and developments in regional national integrated cyber-infrastructure systems, there was a shift from the initial SADC HPC (High-Performance Computing) Framework (2016) to a holistic, integrated Cyber-Infrastructure Framework (2016).

The SADC Cyber-Infrastructure Framework forms a basis for a SADC Cyber-Infrastructure Strategy and Action Plan in the SADC region. It also proposes an implementation plan and governance structure for such a cyber-infrastructure strategy. A SADC Cyber-Infrastructure Strategy and Action Plan supports the implementation of the approved SADC Strategic Plan on Science, Technology and Innovation (STI) and also contributes

[53] https://www.nepad.org/programme/african-science-technology-and-innovation-indicators-astii
[54] http://aosti.org/

concretely to the R&D, Innovation and Industrialisation pillar of the Digital SADC 2027[55] initiative. The vision of the Digital SADC 2027 initiative is to develop a solid information and communication technology infrastructure, addressing broadband challenges, affordable high-speed Internet, developing human capacity and skills in ICT technologies, and more. The SADC Strategic Plan on STI[56] is a five-year plan (2015–2020), guiding the region to create an enabling environment to harness science, technology and innovation as a tool to address socio-economic challenges for sustainable development in the region. This framework has been developed to also support the implementation of the Protocol on Science, Technology and Innovation; Revised Regional Indicative Strategic Development Plan (RISDP); Industrialisation Strategy and Roadmap, and Regional Infrastructure Development Master Plan (RIDMP). It not only provides direction to the 16 SADC member countries, but can also be considered to be adopted by other regions on the African continent.

E-Infrastructure, including bandwidth and connectivity, networking, high performance computing and data stewardship are essential priorities for science in Africa. Challenges identified as part of the landscape study have been listed as part of Section 6.1. See the maps for connectivity (Figure 8) and IT infrastructure (Figure 9) on the African continent for a visual representation of the data under discussion in this section.

4.2.1 INTERNET BANDWIDTH AND CONNECTIVITY

4.2.1.1 National Research Education Networks (NRENs)

GÉANT[57] defines NRENs as "organisations that are specialised Internet Service Providers (ISPs) dedicated to supporting the needs of the research and education communities within their own country." They are an evolution of academic networks that use Internetworking Protocols (IP), and preceded commercial public ISPs. NRENs are private IP-based academic networks operated by non-for-profit organisations often controlled and owned by academic communities. Most African NRENs are endorsed by their respective governments and benefit from tax waivers or exemptions, free operator licenses or even Universal Service Funds, e.g. in Uganda and Zambia[55].

The concern however, is that selected African governments (with the exception of a few countries such as South Africa, Mozambique, Ethiopia and others) have low awareness of how the Internet works, how much ICT (and the 4th Industrial Revolution) have affected research, and the added value an NREN – through being connected to fellow NRENs – can bring to higher education and research in addressing the respective needs, which is far more complex than simply providing connectivity (Foley, 2016). A main threat to NRENs in selected African countries is commercial public ISPs influencing governments, sometimes creating the impression that NRENs offer nothing more than what commercial

[55] https://www.sata-sec.net/board/downloads/11%20April%202018/New%20Initiatives%20with%20high%20impact.pdf
[56] https://www.sadc.int/files/5415/2109/8240/SADC_Revised_RISDP_2015-2020.pdf
[57] https://www.geant.org/

Internet Service Providers (ISPs) offer[58]. Galagan and Looijen (2015) confirm that each of the NRENs and Regional RENs have their own political, financial and other challenges. The main challenge is the unaffordability of telecoms' pricing in many markets across the continent. Private industry Internet service providers (ISPs) have monopolies in many African countries (especially in Central and West Africa), closing down access to cable landing stations, which keep Internet connectivity very expensive in these countries within a closed market, not allowing other competitors to also enter the market. This makes collaboration and participation with other NRENs, and the roll out of initiatives such as AOSP, impossible in those countries.

This while services offered by NRENs differ markedly from those of a commercial ISP, to the extent that many of these services are impossible to obtain from commercial operators, either because they would be prohibitively expensive or because they would not be provided under any circumstances[59]. Examples of the latter instance are optical lightpaths and, generally speaking, dedicated layer two circuits, both of which are often provided by NRENs (sometimes by NRENs acting in collaboration with one another) to service complex research projects. According to Greaves[56], even when NRENs are providing bandwidth services that are similar to those of ISPs, these are technically configured to maximise benefit to researchers. Thus NRENs provide high-speed optimal paths to other NRENs and to Open Exchange Points, both of which are characteristic features of international NREN collaboration. These paths and points of interconnection facilitate high-speed reliable transfer of data, particularly Big Data, and provide throughput that is generally difficult or even impossible to achieve through commercial services.

The value-added services that advanced NRENs provide are generally oriented towards augmenting or facilitating research collaboration, or solving basic problems that arise from researchers' requirements of networking[56]. A typical case in point is eduroam[60], in respect of which it is common for NRENs to act as National Roaming Operators (NROs), the basic agents of delivery for eduroam. Similarly identity federation is a fundamental enabler of access to a wide variety of services and resources. Interfederation multiplies the effectiveness of these federations, making many thousands of services and resources available through eduGAIN[61].

An increased number of Internet exchange points (IXPs) – at least one per region and one per country – are well on their way. The IXPs are expected to catalyse the build-out of terrestrial infrastructure, which in turn will make access to the Internet cheaper and faster.

On policy level, and according to the HIPSSA ((Harmonization of ICT Policies in Sub-Saharan Africa) – Access to Submarine Cables in West Africa – Assessment Report[54], "appropriate regulation of the telecom sector, and in particular of bottlenecks which curb

[58] Prof Meoli Kashorda, personal email communication on 13 May 2019
[59] Duncan Greaves, personal email communication on 13 May 2019
[60] https://www.eduroam.org/
[61] https://edugain.org/

the development of competition, has positive effects in terms of investment, digital uses growth and therefore a positive impact in terms of economic and social development". The study further identified potential bottlenecks in access at an affordable price to the international capacity of submarine cables and it suggested means and tools used by regulators to remedy them. Work on the recommended measures and making them operational continues in collaboration with WATRA (the West Africa Telecommunications Regulators Assembly).

See Table 3 for the status of NRENs on the continent according to the Capability Maturity Model[62] developed by Duncan Greaves (2009). This summary by Foley (2016) is useful for a better understanding of the capabilities of NRENs on various levels. According to studies by Foley (2016) and Greaves (2009), 18 of 54 African countries have actual and operational NRENs (Levels 4 to 6). 23 of 54 African countries have made some progress and are committed, but have not implemented yet (Levels 2 and 3). 13 of 54 African countries do not have NRENs yet (Levels 0 and 1).

Level 0	**No NREN and no awareness** of the need. This occurs in countries where there are a number of factors at work that inhibit the establishment of an NREN, such as lack of awareness of the nature and benefits of an NREN, lack of physical network infrastructure, or its high cost. The commodity Internet is seen as sufficient for the needs of the universities.	Central African Republic, Djibouti, Republic of the Congo, Lesotho, Libya
Level 1	**No NREN but a diffused consciousness of the benefits** of establishing one. A bandwidth shortage can lead to the formation of a 'buying club' for purchasing bulk bandwidth from an ISP. It is the beginning of a consortium that could be developed into an NREN.	Angola, Comoros, Eritrea, Seychelles, South Sudan, Equatorial Guinea, Guinea Bissau, São Tomé and Príncipe
Level 2	**No NREN but a more structured conversation** regarding one. This is the stage at which the group of champions has a more focused view of what is required and begins to approach university management and government for support. It can be prompted by changed conditions, donor prompting, regulatory improvements, but it requires strong leadership to proceed to the next level.	Botswana, Democratic Republic of the Congo (2.5), Malawi (2.5), Mauritius, Rwanda, Somalia, Swaziland, Zimbabwe, Cape Verde, Chad, Gambia, Guinea, Liberia, Sierra Leone, Mauritania
Level 3	**No actual NREN but a formal commitment** to proceed is achieved. The consensus is formalized with signed memorandums of understanding between institutions promising to collaborate, and recognized by government, but before a physical network is established. Staff in universities and ministries are still working on a voluntary basis at the planning stage. This is a delicate stage and progress needs to be seen to keep the consensus alive.	Benin, Burkina Faso, Cameroon, Gabon, Ghana (3.5), Mali, Niger, Togo
Level 4	**A formal NREN organisation with services is established.** A legal entity with paid staff and power to make contracts and offer services. Connectivity is provided to members through contracts with providers for services, and a business plan and business model is being implemented. It remains vulnerable to predatory	Burundi, Ethiopia (4.5), Madagascar, Mozambique (4.5), Namibia, Sudan (4.5), Tanzania (4.5), Côte d'Ivoire, Nigeria, Senegal,

[62] https://repository.ubuntunet.net/handle/10.20374/69

	competition from commercial operators because it is not yet able to provide the advanced services that distinguishes it from an ISP.	Morocco (4.5), Tunisia (4.5)
Level 5	**First REN to REN international links are established.** The benefits include faster connectivity to remote academic resources and participation in the wider global and/or regional REN community.	Uganda, Zambia
Level 6	**The NREN begins to offer REN-specific advanced services.** This stage marks the full maturity of the NREN as it delivers value-added services specific to academic collaboration such as federated identity services, access to grid computing, science gateways, user-controlled lightpaths, and so on. This is where the NREN comes into its own.	Algeria, Egypt, Kenya, South Africa, [Zambia – 2019]

Table 3. NREN status of African countries (Foley, 2016; Greaves, 2009)

4.2.1.2 Connectivity among NRENs

Both the Kenya NREN (KENET, established in 1999) and the South African NREN (TENET, established in 1998) connections to GÉANT were in place before the initiation of the AfricaConnect projects. Both these NRENs, as well as the Mozambique NREN MoRENET, were established with USAID, African Partnership for Higher Education (APHE) and local government funding. The AfricaConnect project (AfricaConnect (2012–2014) and AfricaConnect2 (2016–2018)) however contributed to expanding the implementation of a high-capacity Internet network for National Research and Education Networks (NRENs), connecting selected remaining NRENs with one another. Inland (landlocked) countries such as Uganda and Zambia have significantly benefitted from the AfricaConnect projects[63].

The AfricaConnect project – through the NRENs – aims to support the fulfilment of the region's Millennium Development Goals (MDGs) and SDGs, open up research activities in the region, reduce poverty, brain drain and the digital divide. 80% of funding for this was provided by the Directorate-General for International Cooperation and Development (DG DEVCO) through European Development Funds (EDF), and as a result of the ACP-EU Partnership Agreement ("Cotonou Agreement"), signed in Cotonou on 23 June 2000[64], which was concluded for a 20-year period from 2000 to 2020. It is the most comprehensive partnership agreement between developing countries and the EU. This agreement expands well beyond the scope of AfricaConnect and sets the legal basis and rules for development aid in Africa. The remaining 20% of the funding was provided by the Eastern and Southern Africa partners on the basis of a cost-sharing model. Without financial commitment from African governments, NRENs are under threat and might not be sustainable, being dependent on monies from outside Africa.

AfricaConnect2 extended the scope of its predecessor (AfricaConnect) to a Pan-African level by connecting North, West and Central Africa, and supporting these regions through

[63] Prof Meoli Kashorda, personal email communication on 13 May 2019
[64] https://ec.europa.eu/europeaid/regions/african-caribbean-and-pacific-acp-region/cotonou-agreement_en

a modular approach adjusted to specificities of the African sub-regions (see Figure 8). The link between Lagos (Nigeria) in the WACREN region and London (United Kingdom) has been etsablished.

AfricaConnect2 comprises of three geographical areas (clusters) – ASREN, WACREN and the UbuntuNet Alliance. Each region follows a different membership approach, and not all members are connected. The following countries are members, and those in red are members of a specific region, but were not connected by the time of this landscape report (June 2019).

- **ASREN**[65] in North Africa (connecting the Arab countries, as well as Algeria, Egypt, Lybia, Mauritania, Morocco, Tunisia). Summary: 4 connected countries; 2 countries net yet connected.
- **WACREN**[66] in West and Central Africa (connecting Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Gabon, Ghana, Guinea, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo). Summary: 3 connected countries; 11 countries not yet connected.
- **UbuntuNet Alliance** [67] in Eastern and Southern Africa (connecting Burundi, Democratic Republic of the Congo, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Namibia, Rwanda, Somalia, South Africa, Sudan, Tanzania, Uganda, Zambia, Zimbabwe). Summary: 10 connected countries; 6 countries not yet connected.

In Figure 9 connected African countries are colour-coded by their regional cluster.

[65] http://asrenorg.net/?q=content/arab-nrens
[66] https://www.wacren.net/
[67] https://ubuntunet.net/

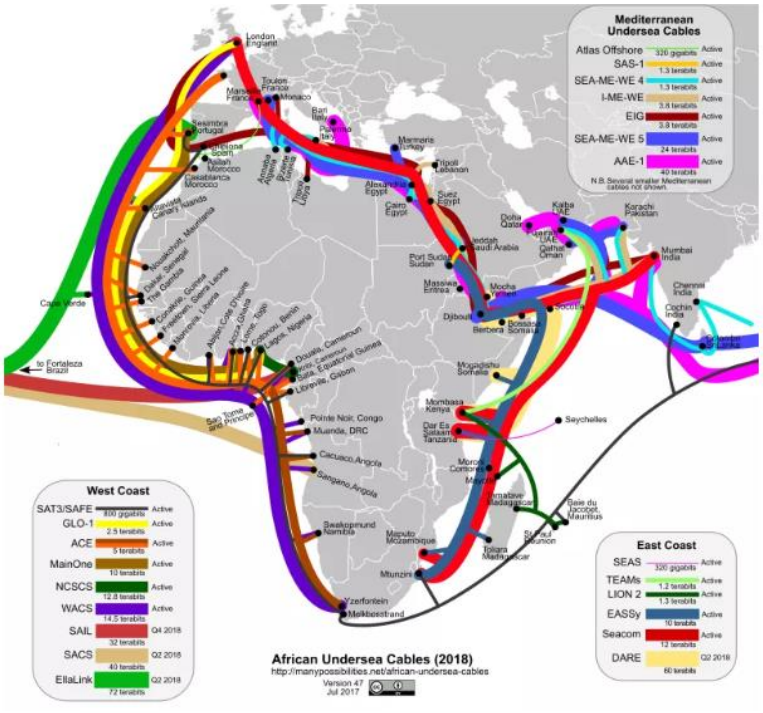


Figure 8. Sub-marine fibre cables reaching Africa, up to 2018[68]

Preparations are in place towards an AfricaConnect3 project starting at the end of 2019. The focus of AfricaConnect3 will be to accelerate progress in the research and education process, which is in alignment with the priorities of the Digital4Development[69] (D4D) strategy. The D4D strategy "encourages to mainstream the use of digital tools across development sectors, with a particular focus on the need to support enabling environments for the digital economy by enhancing open, affordable and secure broadband connectivity, of supporting digital literacy and skills to empower people and promote social inclusion. More specifically, it illustrates the enabling role of digital tools for education and human development."[70]

4.2.2 HIGH PERFORMANCE COMPUTING

With improved connectivity well established and sufficient bandwidth available, more and more NRENs – especially the Level 6 NRENs (Algeria, Egypt, Kenya, South Africa (Foley, 2016)), have implemented or are exploring offering additional services – also in support of data sharing and transfer. The following NRENs already allow for running data-intensive applications and sharing of high-end computing assets, bio-modelling and computation on high-performance/ supercomputers: ARN (Algeria), EUN (Egypt), KENET (Kenya), TENET (South Africa), RENU (Uganda), and ZAMREN (Zambia).

[68] https://manypossibilities.net/african-undersea-cables/
[69] https://ec.europa.eu/europeaid/tags/digital4development_en
[70] https://www.africa-eu-partnership.org/en/projects/africaconnect3

As mentioned in Section 4.2.1.1, 18 of 54 African countries have actual and operational NRENs (Levels 4 to 6). 23 of 54 African countries have made some progress and are committed, but have not implemented yet (Levels 2 and 3). 41 African countries therefore have NRENs which each offer a spread of services, in various stages of commitment and development – from basic connectivity to advanced high performance computing services. The South African Department of Science and Technology National Integrated Cyberinfrastructure System (NICIS)[71] initiative follows a 3-pillar approach. In addition to the South African National Research Network (SANReN) and Tertiary Education and Research Network of South Africa (TENET) (responsible for operating SANReN and additional service offering), it offers 2 more pillars: the Centre for High Performance Computing (CHPC), which provides massive parallel-processing capabilities and services to researchers in industry and academia, and the Data Intensive Research Initiative of South Africa (DIRISA), which implements services that enable sound data management practices and support efficient data-driven scientific and engineering discoveries.

A major collaborative initiative on the continent is the SADC Cyber-Infrastructure Framework (discussed in Section 4.2) approved by the Southern African Development Community (SADC) ministers in 2016.[72] Prior to the SADC Cyber-Infrastructure Framework, a SADC HPC (High-Performance Computing) Framework considered regional infrastructure development; research and development; human capital development, and governance and strategic partnerships around high-performance computing.

High-performance computing capacity in SADC countries, as well as outside the SADC region, currently include, but are not limited to:

- **Algeria** - AUN
- **Botswana** – University of Botswana
- **Egypt** - EUN
- **Ghana** – Ghana Earth Observatory, as part of the HPC Ecosystems Project, part of the first African SKA satellite outside of South Africa and Ghana Atomic Energy Commission (GSSTI /GAEC)
- **Kenya** – Data Centre and Services @ Research and Education Network (KENET) and Nairobi International Livestock Research Institute; Broglio Space Centre
- **Madagascar** – Institut et Observatoire de Géophysique Antananarivo (IOGA)
- **Mozambique** – Part of the HPC Ecosystems Project and SKA
- **Mauritius** – University of Mauritius
- **Namibia** – Namibia University of Science Technology and University of Namibia
- **South Africa** – Centre for High Performance Computing (CHPC) and at 7 SA universities

[71] https://www.csir.co.za/national-integrated-cyber-infrastructure-system

[72] The 16 SADC member countries include: Angola, Botswana, Comoros, Democratic Republic of the Congo, eSwatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia and Zimbabwe.

- **Tunisia** – Data Computing Centre el Khawarizmi
- **Uganda** - RENU
- **Zambia** – ZAMREN

Rolling out high-performance computing infrastructure within the Square Kilometre Array (SKA) African countries[73] is an objective of the High-Performance Computing (HPC) Ecosystems Project[74], towards future SKA collaboration with South Africa, distributing and deploying decommissioned HPC hardware as mid-tier systems to research institutions within Africa.

4.2.3 DATA STEWARDSHIP AND REPOSITORIES

For data to be FAIR it needs to adhere to sound data management principles. In addition to funders making the submission of FAIR data management plans mandatory, libraries on the continent are integrating research data management (RDM) as part of information literacy training. Both the University of Cape Town (UCT) and DIRISA (Data Intensive Research Initiative of South Africa) have implemented online data management tools based on DMPonline Open Source Software[75] developed by the Digital Curation Centre, Glasgow, Scotland – UCT on an institutional level, and DIRISA on national level, with the prospect of DIRISA also curating Big Data generated through the SKA set of telescopes.

To understand the landscape in terms of data curation, a full evaluation will have to be conducted of individual data repositories on the continent. It was clear by observation that few repositories use proper data repository software or science gateways, tailor-made for purpose, adhering to international best practise regarding persistent identifiers, metadata, licensing, IPR, data citation, archiving, and back-up of data. Ideally all data repositories should be listed with the Registry of Research Data Repositories[76] and adhere to the requirements of the CoreTrustSeal[77].

4.2.4 SCIENCE GATEWAYS

The majority of data repositories that were identified are stand-alone web pages or databases, with the exception of the data repositories part of science gateways. Indiana University (2019)[78] defines a *science gateway* as

> "an interface designed specifically to support a particular type of scientific research, with an emphasis on supporting the entire scientific process from start to finish. Science gateways require considerable effort to create, and are typically designed to help an entire community of researchers use high-

[73] Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, South Africa, and Zambia
[74] https://www.csir.co.za/open-call-applications-high-performance-computing-ecosystems-equipment
[75] http://www.dcc.ac.uk/DMPonline
[76] https://www.re3data.org/
[77] https://www.coretrustseal.org/
[78] https://courses.airavata.org/

performance computing resources and advanced cyberinfrastructures to pursue common scientific goals."

Sci-GaIA[79] (2015) – a former H2020 project funded by the European Commission (DG CONNECT[80]) promoting the development and use of e-Infrastructures in Africa – describes a science gateway as a "community-development set of tools, applications, and data that is integrated via a portal or a suite of applications, usually in a graphical user interface, that is further customised to meet the needs of a specific community". According to Sci-GaIA (2015) science gateways enable communities of practice (CoPs) to seamlessly exploit various kinds of distributed computing and storage resources (Grids, Clouds, HPCs) through a common interface that is configured to fulfil their requirements. Science gateways can also foster collaborations and the exchange of ideas among researchers.

Six science gateways were created in the course of the Sci-GaIA project (May 2015–April 2017) by and for African communities of practice. They join the Africa Grid Science Gateway[81], which was also supported by the project, but which was created during the previous eI4Africa[82] project. eI4Africa was a FP7 project funded by the European Commission (DG CONNECT) with the aim of boosting the Research, Technological Development and Innovation (RTDI) potential of African e-Infrastructures and to support policy dialogues and Euro-African cooperation in the framework of the joint Africa-EU Strategic Partnership. According to the Sci-GaIA website, the following science gateways were implemented as part of the project:

- **MIPAR (Medical Image Processor and Repository) Portal**[83] – An e-infrastructure for sharing and analysing medical images. MIPAR comprises a medical image repository and specialised image analysis software tools.
- **Kenya Public Health Gateway (PHG)**[84] – Gateway to mitigate the effects of motorcycle-related accidents in Kenya, which cause more deaths than those involving bicycles and cars. PHG comprises a web interface, through which accident data can be entered, and an app for mobile appliances that uses the GPS functionalities of smartphones and tablets and connects to the PHG metadata server to notify motorcycle drivers in real-time about them approaching/crossing dangerous areas.
- **Technology Transfer Alliance (TTA) Collaboration Platform**[85] – A web-based platform containing an integrated set of tools, applications, data repositories that are accessed via a portal. The aim of this platform is to support collaboration and

[79] http://www.sci-gaia.eu/
[80] https://ec.europa.eu/info/departments/communications-networks-content-and-technology_en
[81] https://sgw.africa-grid.org/
[82] http://ei4africa.eu/
[83] https://mipar.sci-gaia.eu/
[84] https://phg.sci-gaia.eu/
[85] https://oar.sci-gaia.eu/record/279?ln=en

training and to foster education among the partners, sharing of all sorts of resources and dissemination of results.

- **iGrid Portal** – A portal that aims to design and implement autonomous smart microgrids for off-grid rural communities in Tanzania. The iGrid portal is interfaced to the Sci-GaIA OAR (Open Access Repository) for storing documents, datasets and other research products. A DataCite-issued Digital Object Identifier (DOI) is automatically assigned by the OAR to each iGrid record to improve its findability, discoverability and reusability.
- **PLANTISC-2 Science Gateway** [86] – Plant Tissue culture is a method for plant propagation under *in vitro* conditions. PLANTISC-2 is a simulation application that predicts the desired hormonal combinations using provided input data. A two variable multi-Regression is used for the prediction.
- **AgriSERVICOMM Science Gateway** [87] – AgriSERVICOMM implements a novel communication model/platform using science gateways and e-infrastructures to achieve enhanced agricultural extension practice and improved productivity for the rural farmers.

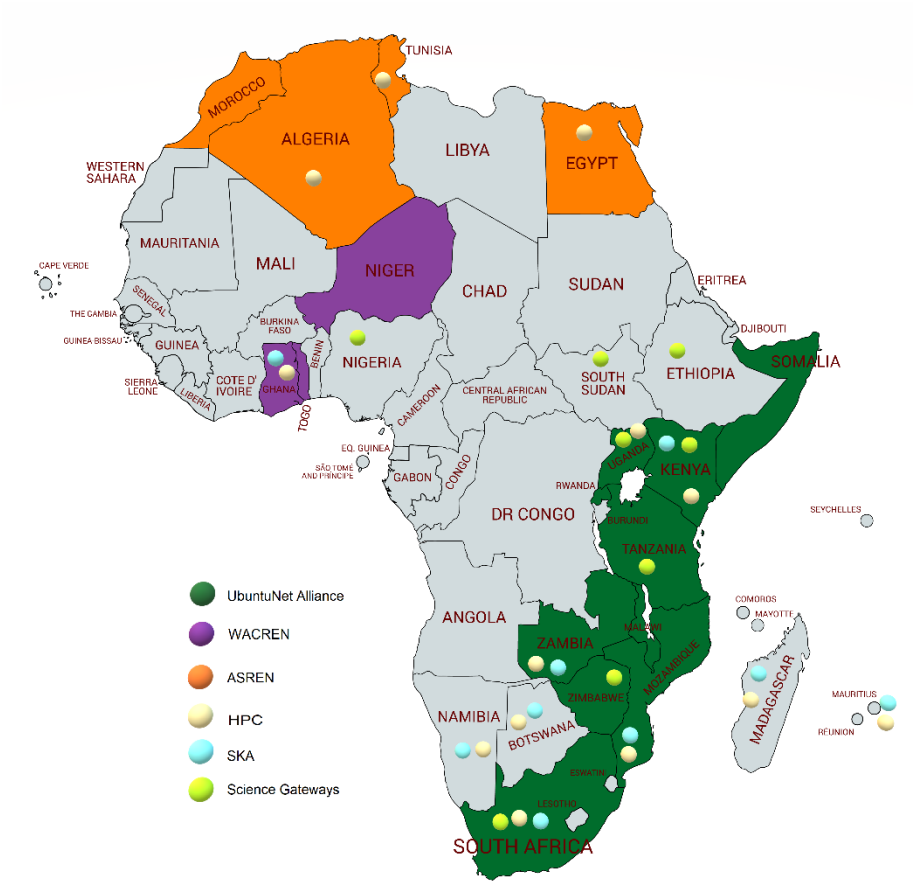


Figure 9. Map of countries with NRENs connected, as well as HPC, SKA and Science Gateways

[86] http://www.sci-gaia.eu/community/plantisc2/
[87] http://www.sci-gaia.eu/community/agriservicomm/

4.3 EDUCATION AND SKILLS

Examples of universities and institutes where data science is already being taught are listed as part of Section 3.4.1. While courses are developed for teaching purposes, collaborations with experts outside of the African continent are still the preferred means for the analysis of Big Data.

NRENs, such as KENET (Kenya), offer training related to services offered and network management, but also blockchain and other technologies, while the Centre for High Performance Computing (CHPC) in South Africa offers training in programming and data processing. In many cases, training is also offered as part of funded programmes (e.g. H3ABioNet bioinformatics training and GBIF through its Biodiversity for Development Programme).

Both formal studies and short courses can be regarded as efforts towards continuing professional development (CPD), which is increasingly a requirement as part of the world of work within a fast-paced technology-driven society. Short courses that could be identified are presented by a limited number of universities:

- UCT e-Research, University of Cape Town (South Africa)
- dLAB, University of Dar es Salaam (Tanzania)
- Explore Data Science Academy (EDSA) (South Africa) - https://www.explore-datascience.net/
- WeThinkCode (South Africa) - https://www.wethinkcode.co.za/
- 10 Academy - https://www.10academy.org/

However, international online courses can also be utilised for further training, and are open for anyone to enrol. Some of the available examples include:

- Open Science MOOC – https://opensciencemooc.eu/
- Coursera Data Science – https://fr.coursera.org/specializations/jhu-data-science
- Coursera Research Data Management and Sharing – https://www.coursera.org/learn/data-management
- FOSTER Open Science Courses – https://www.fosteropenscience.eu/
- MANTRA for Researchers – http://mantra.edina.ac.uk/
- MANTRA for Librarians – http://mantra.edina.ac.uk/libtraining.html
- Agricultural Information Management Standards (AIMS) – http://aims.fao.org/online-courses

The CODATA-RDA Schools of Research Data Science aim at addressing the need for foundational data skills across all disciplines. These skills include the principles and practice of Open Science and research data management and curation, the use of a range of data platforms and infrastructures, large-scale analysis, statistics, visualisation and modelling techniques, software development and annotation. A number of delegates

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

have been funded by AOSP to participate in these data schools. In 2017, three participants attended this programme in Trieste and in 2018, three in Rwanda. The project also participated in and funded the first AOSP Data Science School, in collaboration with CODATA and RDA, during June 2019, in Addis Ababa, Egypt.

Open licensed educational material available for teaching can be found online, and customised according to needs experienced:

- Author Carpentry – https://authorcarpentry.github.io/
- Data Carpentry – http://www.datacarpentry.org/
- Library Carpentry – https://librarycarpentry.github.io/
- World Data System (WDS) Training Resources – https://www.icsu-wds.org/services/training-resources-guide/

The Carpentries[88] – teaching foundational coding and data science skills to researchers worldwide – up to date trained 19 instructors from Africa, presented 110 workshops on the continent, and trained 1,577 delegates from Africa.

International data training by FOSTER Plus, CESSDA, OpenAIRE, ELIXIR, DANS and EIFL – focusing on social/life sciences in Europe mostly – have not been explored as part of this landscape study.

4.4 RESEARCH CULTURE (BARRIERS AND INCENTIVES)

Incentives to encourage data sharing have been discussed in great detail in previous reports, e.g. Sowing the Seed: Incentives and motivations for sharing research data, a researchers' perspective[89], by Knowledge Exchange[90].

Incentives can include:

- a requirement by funders as a condition of grant;
- use of a sharing metric as a basis for recognition and promotion;
- peer pressure for sharing as a normative principle;
- a supportive research environment;
- institutional policies, and
- recognition of the value of sharing to a researcher.

According to the *AOSP Incentives Framework* developed by Bezuidenhout (2019), there are a number of barriers that unnecessarily undermine Open Data practices. One of the barriers is where full disclosure of the data is not always possible, particulary within medical research and relating to privacy, safety and security (Kaye *et al.*, 2009; Knoppers *et al.*,

[88] https://carpentries.org/
[89] http://www.knowledge-exchange.info/projects/project/research-data/sowing-the-seed
[90] http://www.knowledge-exchange.info/

2011). Further to this, where research is externally funded or intended for commercial exploitation, data and the research can require IP protection. Ferguson (2014) regard the following as further barriers, discussed in brief: publication-focused metrics; traditional authorship attribution structures; shortages of resources; lack of skills, awareness and training; a necessary diversity in practices and policies, intellectual property issues and ethical concerns. The mentioned barriers are not restricted to Africa only, and are experienced as challenges by researchers worldwide.

4.4.1 PUBLICATION-FOCUSED METRICS

Publication-focused metrics are heavily used within African academia as a means of evaluation. This is often only one of very few – if not the only – criteria determining promotion. Empirical studies have shown that the pressure to publish in peer-reviewed journals influences perceptions of Open Data amongst African academics, making them disinclined to disseminate data until they have exhausted publication possibilities (Bezuidenhout et al., 2016).

4.4.2 TRADITIONAL AUTHORSHIP ATTRIBUTION STRUCTURES

Attributing authorship in academic publications has not kept pace with developments in data science. As a result, the contributions – particularly technical – of some academics are consistently undervalued, making them less willing to engage in future projects. This becomes even more complicated when original data is re-used, and the original data contributor is not acknowledged.

Concerns about being "scooped" are further highly prevalent within African academia. This is undoubtedly influenced by the historic legacy of unethical "parachute research" (Heymann, Liu, and Lillywhite, 2016), whereby African contributors were excluded from credit for their work on international projects. Traditional authorship practices therefore can undermine Open Data practices.

4.4.3 SHORTAGES OF RESOURCES

Funding for data sharing activities varies considerably, and many research grants continue to lack dedicated funds for Open Data activities. Shortages of dedicated resources for data sharing activities, together with concerns about the longevity of digital repositories (Tenopir *et al.*, 2011; Leonelli, Spichtinger, and Prainsack, 2013) are significant barriers to the evolution of Open Data practices. Low levels of project funding, poorly financed research institutions and low national investment in ICT infrastructures all combine to challenge data sharing activities on the African continent.

The challenges that low-resourced settings pose to data sharing practices are further compounded by the design of the Open Data tools themselves. Open Data implementation has been noted to focus predominantly on high-resourced, and internationally well-recognized research environments (Leonelli, 2017). As a result, many

of the resultant tools are designed with a high-resourced setting in mind. This leads to issues such as the dominance of English as the user language, the use of graphic-intensive platforms that may be inaccessible in low-bandwidth environments, and reliance of expensive proprietary software. These characteristics can serve as significant deterrents to data sharing activities by African scientists (Bezuidenhout *et al.*, 2017).

4.4.4 LACK OF AWARENESS, SKILL SHORTAGES AND SHORTAGE OF TRAINING

Despite concerted efforts to raise awareness about Open Data issues, there remains considerable confusion within the global research community about "what openness means in practice, what options are available to implement it, what is legal, what is recommended by funders, learned societies, publishers, research institutions and governmental bodies, and whether such recommendations are compatible with one another" (Leonelli 2017, 10).

A further widespread absence of training in RDM and associated data science skills, particularly on the African continent, contributes to this barrier.

4.4.5 DIVERSITY OF PRACTICES AND POLICIES

There is no "one size that fits all" when it comes to data sharing practices (International Council for Science *et al.*, 2015). Big Data offers unique challenges because of the expansion of the Volume, Variety and Velocity (VVV) of data. Requirements in terms of managing the richly diverse and heterogeneous "long tail" small data sets are also lacking, often disappearing along with obsolete hardware/software or when the researcher is no longer around. A lack of data sharing or data management policies on the continent is a major barrier.

4.4.6 INTELLECTUAL PROPERTY CONCERNS

For African researchers, intellectual property issues are compounded by a number of distinct challenges. First and foremost, in many countries the intellectual property landscape surrounding research outputs is incomplete or emerging, which offers little protection to researchers wishing to protect their knowledge outputs. Similarly, many institutions do not have dedicated staff to offer intellectual property advice, which implies that researchers have to navigate complicated legal landscapes on their own. According to Terroir (2016) "[I]in many African countries, intellectual property protection is undeveloped, ineffective, expensive and unenforced and in some African countries there exists uncertainty on protection of IP and the threat of innovation being stolen away from inventors."

Intellectual property issues also contribute to concerns about scooping in two different ways. In a qualitative study of scientists in Kenya and South Africa, Bezuidenhout and colleagues reported how researchers were unwilling to share data due to their perceptions that their institutions and national intellectual property regulations would not

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

be able to sufficiently protect them against data theft or misuse (Louise Bezuidenhout *et al.*, 2017*)*. Many of the scientists interviewed felt that their institutions would not have the resources to challenge potentially negative actions from research groups from a high-resourced, foreign institution.

Another complicating factor for African researchers relates to the widespread tendency of researchers using personal funds to finance research activities. Many researchers make the decisions to invest their personal money into their research career strategically, with clear expectations of promotion (via publication) or intellectual patent rewards (Bezuidenhout *et al.*, 2017). These personal investments significantly influence attitudes to openness and sharing, and present challenges to nascent Open Data cultures.

4.4.7 ETHICAL CONCERNS

Issues of privacy, data ownership and informed consent have always been part of responsible medical data management. Transitioning existing practices into an Open Data thus poses considerable challenges for researchers, and continue to be, intensely discussed (Knoppers *et al.*, 2011; Kaye *et al.*, 2009, 2018).

The Open Data milieu also raises new ethical problems that require constant attention. In particular, the implications of unanticipated data re-use, the impact of linking disparate data sets, Big Data mining and the use of surveillance technologies and artificial intelligence all raise important ethical concerns. While many researchers recognize that their work may have ethical implications, training in ethics of data usage is not widespread. Furthermore, training in ethics as well as the review of projects by research ethics committees is commonly limited to researchers working with human or animal subjects. For many other researchers there is a justified feeling of being underprepared and ill-equipped to deal with the ethical complexities of data sharing.

4.4.8 INFRASTRUCTURE

Africa has enormous infrastructure gaps, including broadband infrastructure, and access to broadband services, where they exist, is also very expensive (Economic Commission for Africa, 2017). Moreover, personal connectivity costs remain extremely high in most African countries (Alliance for Affordable Internet, 2017). Issues of connectivity are further complicated by ageing and unreliable power infrastructures and frequent power outages.

4.4.9 LACK OF HARDWARE AND SOFTWARE

Availability of up-to-date ICT hardware and proprietary research software is problematic for many researchers in Africa (Bezuidenhout *et al.*, 2017; Harle, 2010; Vermeir *et al.*, 2018). Moreover, the cost of purchasing regular software updates is often viewed as prohibitive (Bezuidenhout *et al.*, 2017). Due to these challenges, the use of pirated software, older versions of software or free trial software are all commonly used. Interestingly, a recent

survey suggested that the use of Free and Open Source Software (FOSS) is not widespread within many research communities in Nigeria and Ghana (Vermeir *et al.*, 2018). It is highly likely that this is the case in many other African countries as well. Poor connectivity, unaffordability of data to download applications, lack of proper infrastructure, and a shortage of skills might be some of the reasons behind the low adoption of FOSS.

4.4.10 RESEARCH CULTURES

Despite a growing amount of support for Open Data, awareness of the Open Data movement remains low within African academia. These are grouped in Table 4.

Area of Impact	Specific Challenge
Low interaction with Open Data discussions by African Researchers	Lack of traditionsof openness within work cultures and conservative/traditional academic systems
	Limited engagement of African scientists in Open Data discussions (particularly outside of research networks and centres of excellence)
	Languages – dominance of English in Open Data discussions can marganalise non-native English speakers
Complicated ethical and legal frameworks	Patchy ethics training for RCR and shortage of ethics instructors
	Absent or incomplete data regulation and ethical guidelines
	Absence of coherent institutional and national IP strategies (due to national IP laws differing in relevant ways)
	Conflicting or incomplete institutional, funder and national data sharing strategies
	Limited engagement of academia in national policy and governance
Lack of positive examples of open African research	Perceptions of scooping and evidence base dominated by negative, rather than positive, examples
	Concerns about citation, credit and attribution
Skills shortages	Shortage of data science skills
	Shortages in training for RDM and FAIR. Prevailing lack of funds/support for "soft skills" training and lack of support for social science input in data activities
	Existing skill shortages in technical support, library services and data management/curators
Financial barriers	Scarcity of research funds and use of personal funds to generate data
	Costs of hardware and software needed to support data sharing
Utility of data	Available data not aligned with research interests

Table 4. Challenges to Open Data relating to research cultures

4.4.11 AWARDS

The landscape study identified a few examples of awards through which ICT and data related activities are acknowledged:

- **South African National Science and Technology Forum (NSTF) Data for Research Award** – awarded for an outstanding contribution to science, engineering and

technology (SET) to an individual or a team by advancing the availability, management and use of data for research.

- **Kenya Open Data Awards** – awarded to stakeholders in the Open Data space who have created out of the box solutions/innovations that make it easier for users to access and use Open Data through apps, websites, Internet of Things devices and even blogs that concentrate on making data open and accessible.
- **Open Data Institute Open (ODI) Data Awards** (including a business award, an innovation award, a social impact award, an individual champion award, and a data publisher award) – awarded annually, awarding initiatives and organisations for building an open, trustworthy data ecosystem, where people can make better decisions using data and manage any harmful impacts.
- **UN Data for Climate Competition** – an open innovation challenge to harness data science and Big Data from the private sector to fight climate change. The challenge aims to leverage private Big Data to identify revolutionary new approaches to climate mitigation and adaptation.
- **UN Human Development Data Visualization Challenge** – a data visualization challenge for students, researchers, data users, data scientists, data visualization developers and others to share their interpretation of inequality in human development using a novel and thought-provoking illustration of data.
- **African Network Information and Infrastructure Award** – Although not related to Open Data or Open Science, this award acknowledges excellence amongst Africa's infrastructure investors, to a growing Pan-African and global infrastructure investment and development finance community.
- **African Union Kwame Nkrumah Awards for Scientific Excellence (AUKNASE)** - The AUKNASE programme seeks to raise the profile and role of Science, Technology and Innovation (STI) in the continent and to award top African scientists for their achievements and discoveries in STI. The AUKNASE focuses on two thematic areas: i) life and earth science innovation and ii) basic science, technology and innovation.

4.5 AFRICAN OPEN SCIENCE ACTIVITIES

A number of Open Science initiatives are monitored by international organisations, indicated in each of the sections below. Utilising these databases and indexes identified initiatives representing 32 countries in relation to DOAJ [91] -listed journals, registered repositories (openDOAR [92]), registered policies (ROARMAP [93]), registered data policies (re3data[94]) and the CoreTrustSeal[95] for data repositories.

[91] https://doaj.org/
[92] http://v2.sherpa.ac.uk/opendoar/
[93] https://roarmap.eprints.org/
[94] https://www.re3data.org/
[95] https://www.coretrustseal.org/

4.5.1 OPEN ACCESS JOURNALS

200 DOAJ-listed journals

It is estimated that Africa produces only around 0.74% of global scientific knowledge. There is an increase in the North-South divide; publications not listed on international citation indexes are proven to suffer lower visibility, citation, and effect; and these research results make little or no contribution to the existing body of global knowledge. Furthermore, few African researchers form part of editorial boards of international journals. In some instances, African journals are published by publishers in Europe and North America, such as:

- Scientific African – published by Elsevier, Netherlands
- The African Journal of Information Systems – hosted at Kennesaw University, USA
- Journal of Public Health in Africa – published by PagePress, Italy

African scholarly journals are often not online available, and leadership on managing journals in a trusted way not available. Through an Ambassador initiative of the Directory of Open Access Journals (DOAJ), slow progress is being made. Scholarly journals more and more are making the transition to using PKP Open Journal Systems[96], an Open Source journal workflow solution, to publish journals online. African Journals Online (AJOL)[97] another initiative, has been working on assisting journals to make the transition from print to online journals. According to DOAJ, 19 African countries representing 200 of the 12 732 journals are currently listed on this index that provides access to high-quality, Open Access, peer-reviewed journals. Until recently, 200+ journals published by Hindawi appeared under Egypt, which would have brought the number of African journals listed in DOAJ to 400+.

A notable development towards an Open Science publishing approach is the AAS Open Research mega-journal. Using the F1000 publishing platform, AAS Open Research[98] implements open peer review and requires that data underpinning the research findings should be open by default.

The Scientific Electronic Library Online (SciELO) SA[99] hosted by the Academy of Science of South Africa (ASSAf) covers a selected collection of peer-reviewed South African scholarly journals, and forms an integral part of the SciELO Brazil[100] project. Journals are considered for inclusion in SciELO SA when they have received a favourable evaluation after being peer-reviewed. This peer-review is coordinated by ASSAf, and occurs in cycles of 5 years. SciELO SA focuses on strengthening the scholarly journal evaluation and accreditation systems in South Africa.

[96] https://pkp.sfu.ca/ojs/
[97] https://www.ajol.info/
[98] https://aasopenresearch.org/
[99] http://www.scielo.org.za/
[100] http://www.scielo.br/

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

Scienceafrique.org[101] is the result of a need to have a platform to publish scholarly journals and share science in the francophone region. It currently hosts 5 French journals[102]. The vision of this platform is to give African researchers (including Haiti) the opportunity to freely and openly share their research and their texts to build quality African science, visible and accessible to all, from the perspective of cognitive justice and serving the common good.

Open Science and Open Access in Arabic countries such as Algeria, are driven by the DGRSDT (National Council of Scientific Research and Technology of Algeria)[103]. The vast majority of the total of 359 Algerian scholarly journals are only available in print, with 21 available as Open Access and registered in the DOAJ. The DGRSDT strategy includes:

- training editors in managing and publishing scholarly journals;
- promote sharing and collaboration among Algerian editors, and
- promote global collaboration in advancing Open Access.

The aim is for all Algerian journals to make the transition from print to online, and to adhere to the DOAJ criteria for possible inclusion. An Algerian journal portal by the name Webreview[104] has been launched by the Research Centre on Scientific and Technical Information (CERIST)[105] for the science community to publish journals – whether open or restricted access. On institutional level, and similar to South African universities publishing their own journals (e.g. SUNJournals [106] at Stellenbosch University), many Algerian universities prefer to host and publish their own journals. An example from Algeria is the Université de Béjaïa[107] (Belhamel, 2016).

Only one (1) African country thus far is participating in Plan S[108] (i.e. the National Science and Technology Council (NSTC), Zambia)[109] , while none subscribes to AmeliCA[110] yet.

In response to the portentous need of access to scholarly content by the African research community, an additional SPARC Chapter, SPARC Africa[111], has been established and was launched at the International Federation of Library Associations (IFLA) Academic and Research Libraries (ARL) Satellite meeting on the 14th August 2015. The Chapter's primary focus will be to capacitate Africans in academic and research sectors to champion free access to scientific knowledge as a means to alleviate Africa's lack of access to scholarly content.

[101] https://www.scienceafrique.org/a-propos/
[102] https://www.revues.scienceafrique.org/catalog/
[103] http://www.dgrsdt.dz/Fr/
[104] http://www.webreview.dz/
[105] http://www.cerist.dz/index.php/en/service-en/572-scientific-and-technical-information
[106] https://www.journals.ac.za/
[107] http://www.univ-bejaia.dz/revues
[108] https://www.coalition-s.org/
[109] https://www.coalition-s.org/coalition-s-welcomes-its-first-african-member-and-receives-strong-support-from-the-african-academy-of-sciences/
[110] http://www.amelica.org/en/
[111] http://aims.fao.org/activity/blog/sparc-africa-capacitating-africa-towards-access-open-scholarship

4.5.2 OPEN ACCESS REPOSITORIES (INSTITUTIONAL)

174 **institutional repositories (openDOAR)**

Good progress has been made in making research literature output in the form of research articles (second copies), theses and dissertations available in Open Access format, through institutional repositories (IRs). This is a result of awareness and training conducted by the Electronic Information for Libraries (EIFL)[112], Association of African Universities (AAU)[113] and others. African participants further actively participate in the Confederation of Open Access Repositories (COAR)[114].

OpenDOAR[115] is a global directory of Open Access repositories and their policies. 174 repositories from 24 African countries listed information related to language, software, discipline and policy. 76% of the continent use DSpace[116] as software platform and 92% of repositories archive materials in English.

ASSAf – in collaboration with the AAU – have developed a set of trusted institutional repository criteria[117] to guide IRs on implementation and management best practices of institutional repositories, aligned with international standards. High-quality IRs are being harvested through DATAD-R (AAU)[118]. The criteria contained in this instrument are based on criteria from existing instruments, and contextualised for African needs, without sacrificing the rigour of peer review and external examinations, where applicable.

4.5.3 OPEN ACCESS POLICIES

34 **Open Access policies (ROARMAP)**

The Registry of Open Access Repository Mandates and Policies (ROARMAP)[119] charts the growth of Open Access mandates and policies adopted by universities, research institutions and research funders that require or request their researchers to provide Open Access to their peer-reviewed research article output by depositing it in an Open Access repository. Currently 33 Open Access policies are registered representing participation from eight countries. 32 policies are from universities or research institutions, and one from a funder (National Research Foundation, South Africa). The guide to Good practices for university open-access policies[120] by Suber and Shieber (2019) focuses on rights-retention policies. According to this guide, 3 African universities with OA policies have rights-retention OA policies: Strathmore University in

[112] https://www.eifl.net/
[113] https://www.aau.org/
[114] https://www.openaire.eu/coar-e-v-confederation-of-open-access-repositories-2
[115] http://v2.sherpa.ac.uk/opendoar/
[116] https://duraspace.org/dspace/
[117] https://drive.google.com/open?id=0B6w8fGuczhXqZ2hKalNDZVRyaVU
[118] http://datad.aau.org/
[119] https://roarmap.eprints.org/view/country/014.html
[120] https://cyber.harvard.edu/hoap/Good_practices_for_university_open-access_policies

Kenya (2011), Jomo Kenyatta University of Agriculture and Technology in Kenya (2012), and the University of Nairobi in Kenya (2012).

4.5.4 OPEN DATA REPOSITORIES AND SCIENCE GATEWAYS

24 **data repositories (re3data)**

Although only 24 data repositories are registered with re3data.org (Registry of Research Data Repositories), the pilot project identified 66 research data repositories (see Appendix 1). More awareness about African data should thus be created through encouraging data repositories to register with re3data.org. All 66 identified data repositories (international or regional) are hosting Open Data from the African continent. In selected cases (<5), URLs to the repositories would not resolve and the repositories could not be accessed because of a 404 error.

Although a variety of open source data repository platforms are available for the curation of data, very few have adopted these platforms. Only two data repositories utilise Dataverse[121], while a few would regard a web-page listing the data sets as sufficient to be regarded as a data repository. None of the data repositories have implemented Invenio 3[122], which already offers new generation tools required to manage the explosion of data. Former versions of Invenio are however used by six operational data repositories implemented as part of the Sci-GaIA science gateway project (May 2015–May 2017).

Initiatives such as Code for Africa[123] also encourages scientists to deposit their datasets on openAfrica[124], on its website described as Africa's largest volunteer driven Open Data platform. African journals and journal platforms, such as AfricArXiv[125], are currently exploring technical possibilities to synergize the display of research data output along with OA manuscripts.

[121] https://dataverse.org/
[122] https://invenio-software.org/
[123] https://github.com/CodeForAfrica
[124] https://africaopendata.org/
[125] https://info.africarxiv.org/

1	Algeria	19 14 3	17	Mauritius	2
2	Angola	1	18	Morocco	12 2
3	Benin	2	19	Mozambique	1
4	Botswana	2	20	Namibia	2
5	Burkina Faso	2	21	Nigeria	6 21 1
6	Burundi	1	22	Rwanda	1
7	Cabo Verde	2	23	Senegal	2 1
8	Cameroon	1 1 1	24	South Africa	85 38 2 8 ★ 1
9	Cote d'Ivoire	1	25	South Sudan	1
10	Egypt	50 5 1	26	Sudan	9
11	Ethiopia	3 3 1	27	Tanzania	11 1
12	Ghana	5 5 1 2	28	Tunisia	6 1 1
13	Kenya	5 32 13 4	29	Uganda	1 2
14	Lesotho	1	30	Zambia	1
15	Libya	2 1	31	Zimbabwe	11 2
16	Mali	1			

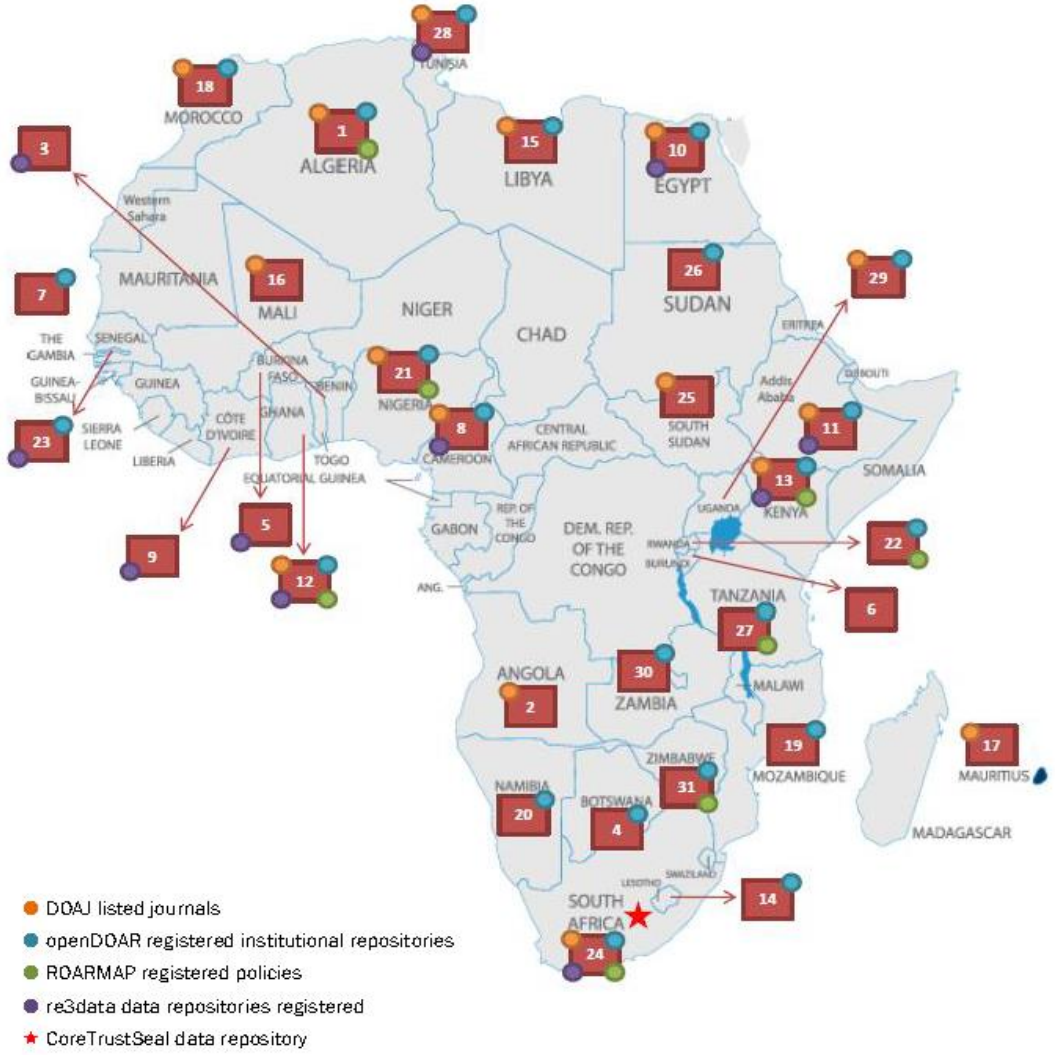


Figure 10. Map of Open Science activities and initiatives on the African continent

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

1	CoreTrustSeal

It is essential that the African research community engage fully with international standardisation mechanisms – both to benefit from their efficiency and to play an active role in their governance and design. This means engagement with international data organisations, those that relate to particular disciplines and those that work across disciplines. Data in data repositories – for global participation – need to adhere to international standards and principles, such as the CoreTrustSeal for trusted data repositories (only one continental data repository carries the seal of excellence); the OECD principles and guidelines for access to research data from public funding (2007) and the FAIR principles[126]. Furthermore, data repositories should also apply open standards for interoperability to ensure re-use across platforms, for data exchange to advance science.

The landscape study collected information on 66 Open Data databases that include or are exclusive to collecting data from the African continent. Eight projects focus on agriculture; eight on health, four are climate-related, five in the field of oceanography, eighteen in the field of biodiversity, with an additional thirteen focusing on geography and five in the field of meteorology. These projects are tabled in Appendix 1 with full lists of participating countries in relation to SDGs. In addition to this, Open Data are also available on astronomy and space sciences through the South African National Space Agency (SANSA) and SKA; word corpora through the SADiLaR Language Resource Management Agency; and resilience studies through the Resilience Atlas in relation to livelihoods, production systems and ecosystems; stressors and shocks; and factors influencing vulnerability.

5. OPEN GOVERNMENT DATA AND OPEN GOVERNANCE

5.1 POLITICAL AND RELATED DEVELOPMENT CHALLENGES

The African continent also faces serious challenges in relation to the use and misuse of technological measures due to political interference, corruption, political conflict, war, Internet censorship and lack of governmental transparency. The graph below (Figure 10) depicts some of the challenges that ultimately affect human development on the continent. It also shows how technology is used for political purposes by governments in times of anti-government protests, specifically for the purposes of influencing national elections. The rise of fake news in relation to African politics is yet another reason why government transparency – by means of Open Data – is of utmost importance for research purposes, data verification and accessibility to the broader public. It is clear from the

[126] https://doi.org/10.1038/sdata.2016.18

Corruption Perceptions Index (CPI)[127] that citizens have little faith in their governments with 46 countries scoring below 50 on a scale of 100 in terms of perception of corruption.

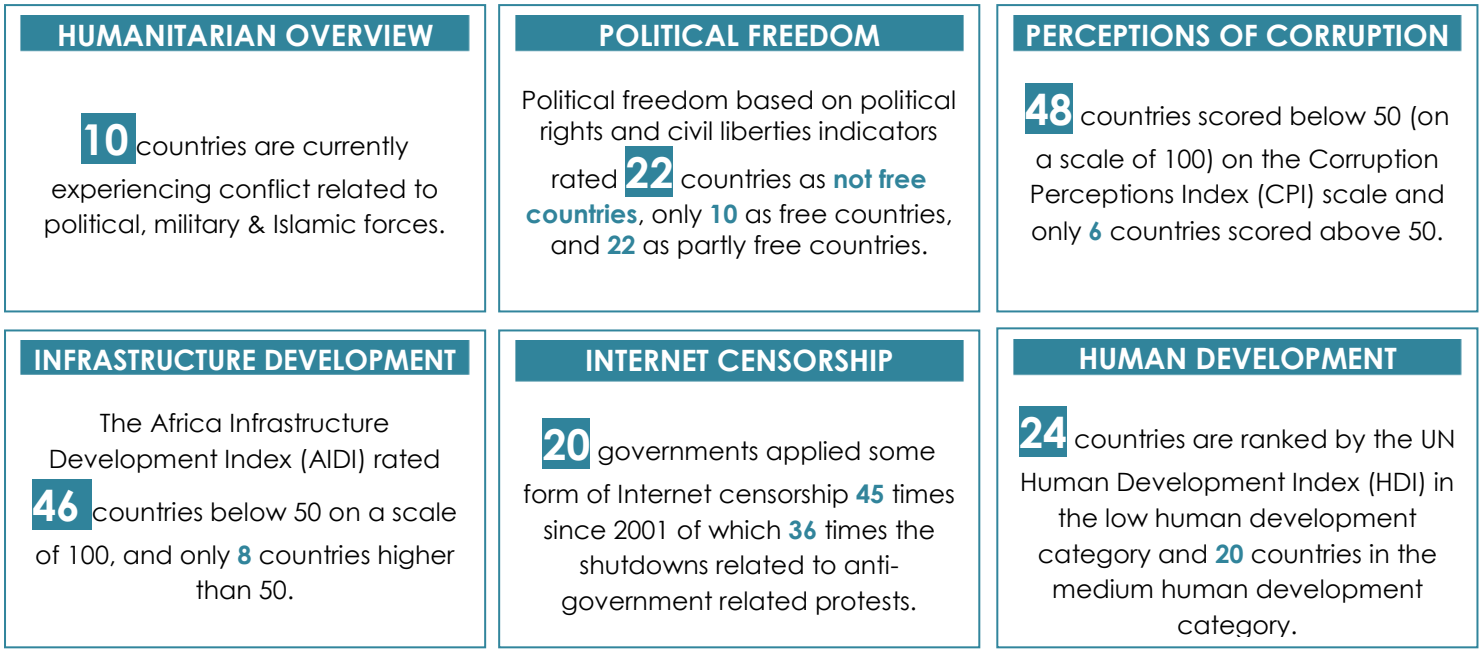


Figure 11. Challenges in Africa, impacting on R&D

5.2 CHARTERS AND DECLARATIONS

A number of charters and declarations in support of open and transparent government data generated limited support. The Kigali Declaration on the Development of an Equitable Information Society in Africa received support from 27 African countries and 4 continental Pan-African socio, political and legal organisations, and the G8 Open Data Charter adopted by 65 countries have one signatory adoption on the continent.

2009	**Kigali Declaration on the Development of an Equitable Information Society in Africa** Underscored the need for mutual assistance, exchange of information, and sharing of experiences and best practices among African Parliaments as recognised by the African Union and Pan-African Parliament in their commitment to the harmonisation of policies and the integration of regional markets.	**27** Algeria, Angola, Botswana, Burkina Faso, Burundi, Chad, Comoros, Congo – Brazzaville, Democratic Republic of Congo, Djibouti, Equatorial Guinea, Ethiopia, eSwatini, Gambia, Ghana, Kenya, Malawi, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, Sudan, Tanzania, Togo, Uganda

[127] https://www.transparency.org/

		4 Pan African Parliament, East African Legislative Assembly, Economic Community of West African States (ECOWAS), SADC Parliamentary Forum
2011	**Open Government Partnership Declaration** The OGP was launched in 2011 to provide an international platform for domestic reformers committed to making their governments more open, accountable, and responsive to citizens.	**12** Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Liberia, Malawi, Morocco, Nigeria, Tunisia, Senegal, Sierra Leone, South Africa
2013	**Africa Data Consensus International (G8) "Open Data Charter"** The leaders of the G8 signed an agreement committing to advance Open Data in their respective countries. This report assesses the current state of Open Data efforts in these countries and finds substantial variation in their progress. Moving forward, countries have many opportunities to enhance their Open Data capabilities, such as by increasing international collaboration, better educating policymakers about the benefits of Open Data, and working closely with civil society on Open Data initiatives.	**1** adopted by Sierra Leone
2016	**Open Data Barometer** The Open Data Barometer is a global measure of how governments are publishing and using Open Data for accountability, innovation and social impact.	**2** signatories – representing Sierra Leone and South Africa

Table 5. Charters and declarations in support of open and transparent government data

5.3 NATIONAL GOVERNMENT DATA INITIATIVES

Government data can be used for research purposes that can support improved governance and evidence-based policy development. Therefore, Open Data (including statistics) by government-controlled entities should ideally be made openly accessible for use, re-use and distribution.

African government data or statistics are key to monitoring the achievement of the SDGs. Government statistics/data further need to be well managed and accessible, since governments are accountable to their citizens, as well as to the international community and aid agencies. Statistics are further key to measuring the progress in terms of democracy and governance in each country. According to Bédécarrats, *et al.* (2016), Africa made notable attempts to address the huge data gap which exists because of a lack of capacity within African statistical institutions, lack of governance of responsibilities regarding statistics, a lack of stable financing from the states, and the disruptive effect of financing by donors in this area. The Strategy for the Harmonisation of Statistics in Africa (SHaSA) [128] (an initiative by the Economic Commission for Africa (ECA), the African

[128] https://au.int/en/ea/statistics/shasa

Development Bank (AfDB), and the African Union (AU)), AFRISTAT[129], and the Pan-African Institute for Statistics (STATAFRIC)[130] are main initiatives towards addressing the data gap between Less Economically Developed Countries (LEDCs) and developed countries.

On a global level, the Sunlight Foundation[131] based in the US also has international reach. It uses civic technologies, open data, policy analysis and journalism to make governments and politics more accountable and transparent to all. The South African government – as a result of buy-in to the Sunlight Foundation – in 2007 announced that it was adopting Free and Open Source Software (FOSS) and Open Document format (ODF) as official standards for government communications. It is however unclear how successful this was.

5.3.1 OPEN DATA BAROMETER

The Open Data Barometer[132] ranks governments based on three criteria: (i) Readiness for Open Data initiatives; (ii) Implementation of Open Data programmes; and (iii) Impact that Open Data are having on business, politics and civil society. This assists to inform government on better decision-making into the progression of Open Data policies and practices.

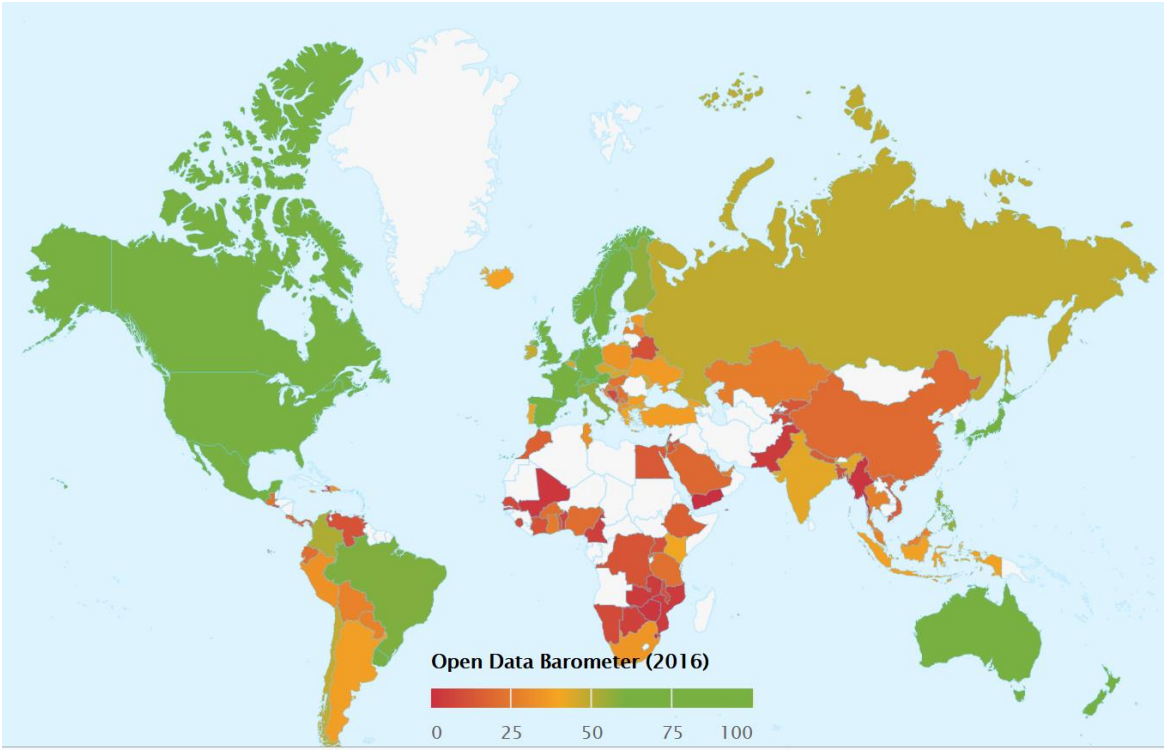


Figure 12. Government Open Data ranking

[129] http://afristat.opendataforafrica.org/
[130] https://au.int/en/ea/statistics/statafric
[131] https://sunlightfoundation.com/
[132] https://opendatabarometer.org/

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

Although 28 countries utilised the barometer to measure their state of openness (as depicted in the Open Data Barometer 2016 charted map), only one African country adopted the barometer's Open Data Charter[133] – Sierra Leone – committing to a globally-agreed set of aspirational norms for how to publish data. South Africa is included as an automatic adopter as part of the G20 and thus the G20 Anti-Corruption Open Data Principles[134]. Only three countries scored above 50 on a scale of 100 in the 2016 edition, indicating the low rate of readiness: Kenya (57/100), Ghana (52/100), and South Africa (51/100). The 2017 edition that rank the two African signatory countries only, demonstrate the extremely low rates of Open Data readiness, as well as the negative impact thereof:

	Political impact	Social impact	Economic impact	Readiness score
Sierra Leone	10.00	20.00	0.00	22/100
South Africa	15.00	25.00	25.00	36/100

Table 6. Rates of Open (government) Data readiness

5.3.2 AFRICAN INFORMATION HIGHWAY

There are currently 28 African Open Data repositories building towards the African Information Highway (AIH): Open Data for Africa Data Catalogue[135]. Open governmental data repositories have been rolled out to all African countries through the African Development Bank (AfDB), to intensify statistical capacity building activities to adhere to the need for data (reliable and up-to-date) for measuring, monitoring and managing for development results. Since launching the AIH, the AfDB has expanded the system to include a variety of topically-specific portals – energy, climate change, infrastructure, health, among others – thus ensuring a single-stop centre for capturing and sharing development data on Africa. The expansion programme has included a notable addition of the SDGs Data Hubs to facilitate monitoring of the implementation of the 2030 Agenda for Sustainable Development across Africa.

5.3.3 OTHER INITIATIVES

During the recent United Nations Statistical Commission for Africa (StatCom-Africa) VI[136] (Ethiopia, 2018), heads of offices from 51 African countries, among other participants, committed to advocate for increased allocation of resources for the production, dissemination and use of statistics to support the implementation of the SDGs. This follows on the Africa Data Consensus roadmap[137], an outcome of the United Nations High Level

[133] https://opendatacharter.net/
[134] http://www.g20.utoronto.ca/2015/G20-Anti-Corruption-Open-Data-Principles.pdf
[135] https://www.afdb.org/en/knowledge/statistics/africa-information-highway-aih/
[136] https://www.uneca.org/statcom-africa-vi
[137] https://www.uneca.org/sites/default/files/PageAttachments/final_adc_-_english.pdf

Conference on the Data Revolution[138] (Ethiopia, 2015) which was organised on request of African heads of state. This articulated its commitment through its vision to partner with all data communities upholding the principles of official statistics, as well as openness across the data value chain. The aim thereof is to create a vibrant data ecosystem providing timely, user-driven and disaggregated data for the public good and inclusive development.

6. GAPS IN THE AFRICAN OPEN DATA/OPEN SCIENCE LANDSCAPE AND THE WAY FORWARD

The preceding sections of this report have dealt with the landscape of activity and capacity in Africa in Open Science, with a specific focus on Open Data. The landscape has areas of serious deficit which need to be corrected if the benefits of Open Science are to be captured and the dangers avoided. This is not an exclusively African problem. Many states and regions globally are grappling with the same issues and attempting to re-configure their science systems for the same reasons. Although Serwadda *et al*. (2018), characterise the problem as one of limited capacity, deep mistrust, digital illiteracy, inadequate infrastructure, and minimal investment in data science training, these are problems, to varying degrees, in all scicnce systems. The African Open Science Platform, as described in the 2018 strategy document (The Future of Science and Science of the Future: Vision and Strategy for the African Open Science Platform), sets out a route to create a distinctively Pan-African response to the challenges. We summarise below key deficits and barriers that need to be addressed in facing the challenges.

6.1 INFRASTRUCTURE (INCL. STEWARDSHIP)

- There is a lack of policy and legal recognition of many African NRENs, who have to rely heavily on funding from member organisations.
- Although NRENs are well positioned to offer services in support of data sharing, they receive limited infrastructure grants or budget support for operational expenditure (OPEX) from their respective governments. They are further poorly understood by the telecom and Internet community, and are regarded as merely specialised Internet service providers that have to compete with very large telephone companies (telcos). Many emerging African NRENs are not operational – with no budget, no dedicated staff and no commitment from the respective higher education and research communities.
- Cloud services require high-speed Internet access/broadband, which are expensive. Funding to offer Cloud services in support of data sharing is lacking.
- Universities and research institutions on the continent have very low research and Internet budgets. Therefore, they face challenges with implementing the necessary infrastructure in support of data sharing.
- Power outages on the continent frequently occur, interrupting Internet service delivery.

[138] http://sdg.iisd.org/events/high-level-conference-on-the-data-revolution-in-africa/

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

- Data repositories – for global participation – should support FAIR data principles and should align with the principles of the CoreTrustSeal for trusted data repositories. At this stage, only one data repository on the continent has been assigned the CoreTrustSeal.
- Projects such as H3ABioNet indicated that a challenge they experience is continent-wide obsolete computer infrastructure that varies between medium-scale server infrastructures to a small number of workstations, with multiple operating systems, and a lack of centralised, secure data storage.
- Researchers and data scientists are often unaware of the availability of Free and Open Source Software tools/applications to collaborate and to share data as part of data-intensive Open Science. Data scientists need to be trained in using FOSS and more awareness to be created.
- The security of data is a huge concern for researchers, and providing a secure infrastructure that can be trusted by researchers, a challenge.
- Due to a lack of trusted data repositories, data often leaves the continent and are then published on platforms published by the Global North, changing ownership.
- Challenges include: lack of awareness of the need for Open Data among selected African governments; poor budgetary allocation for ICT infrastructure and R&D from the majority of African governments; lack of minimum ICT infrastructure requirements and guidelines to support Open Science, and a lack of coordination of existing resources and investment in research infrastructure.

6.2 POLICIES

- There is a lack of policy and legal recognition of many African NRENs, who have to rely heavily on funding from member organisations.
- Data governance, research data and Open Data policies are non-existent both on national and institutional level. Guidelines to implement the policies in the few cases where they exist are unclear.
- Policies are not harmonized and/or aigned.
- Governments in Africa have yet to realise the power of data-driven policies.
- Policies are not implemented quickly. The process of negotiating for an Open Science/Open Data policy often has to start all over once a term of governing is concluded. Because of a lack of policies, data often gets lost or are misplaced.
- IP in Africa and the protection thereof is mostly undeveloped, ineffective, expensive and unenforced. Another concern is that innovation could be stolen as a result of uncertainty about IP policy in the respective countries.
- Often when externally funded projects come to an end, there is little/no contingency, sustainability, funding, and/or political will. This result in data services no longer being available.
- Data is yet to be regarded as an asset – by governments and institutions.

6.3 EDUCATION AND SKILLS

- There is a general lack of data science skills among the various stakeholders supporting and involved in the research process.
- Building and retaining a pipeline of high-end ICT talent to support a small group of researchers in each country is highly challenging.
- NRENs lack full-time senior staff with both research and university experience.
- Limited business and engineering capacity exist to operate the NRENs.
- NREN member institutions demonstrate a low level of Cloud readiness.
- There is a general lack of awareness of Open Science and Open Data, and respective practices among faculty and researchers.
- Short courses try to address the market needs in terms of data scientists. Governments, universities and more should however include data science and/or data literacy as part of discipline-specific curricula. There is still a need for skills development also among professionals as part of CPD.
- Data science training is not well regulated.

6.4 RESEARCH CULTURE (BARRIERS AND INCENTIVES)

- Low awareness of the importance of science, the role of NRENs, and the benefits of sharing data among all stakeholders.
- Absence of policies to guide researchers, and to protect them, at the same time encouraging or making it mandatory to share data for the public good.
- Ethical concerns.
- Full disclosure of data is not always possible, especially within medical research and relating to privacy, safety and security.
- Where research is externally funded or intended for commercial exploitation, data and the research can require IP protection.
- Institutional metric systems rely heavily on publishing in high impact factor journals. Data sharing is not acknowledged for promotion purposes.
- Researchers are hesitant to share data, until they have exhausted publication possibilities.
- Researchers fear that their research might be "scooped" once they share their data. This also a result of "parachute research", where African researchers were excluded from credit for their work on international projects in the past.
- Data scientists are not acknowledged when working on research projects, and when the outcomes of the research are published.
- Research environments are often not conducive for data sharing, and the lack of infrastructure makes it impossible to collaborate and share data.
- There is a lack of incentives in general, e.g. recognition for sharing data sets.
- Curating data is expensive, and often not covered through research funding.
- There is already a lack of publication support for research articles, and even more so, for data.

6.5 CONCERNS BY RESEARCHERS

- Researchers are often uncertain about IP, and ownership that apply to the collected data.
- Researchers have indicated that they are concerned that they will not be acknowledged for their work when sharing their data, and that their research might be scooped or misused.
- A lack of time, expertise, and resources for sharing data exist among researchers.
- Lack of trust on how data are managed, protected.
- Some researchers never thought of sharing data, since nobody has ever asked them.
- There is a silo culture that sometimes exists within research organisations – many researchers prefer to work alone, establishing cultures of non-sharing in organisations.
- Data sharing (including the harmonisation thereof) is often a cumbersome process for researchers, regarded as being administrative, adding unnecessarily work to their already huge workloads.
- Researchers have minimal or no understanding of licenses, and the difference between patents, copyright and licensing.
- Their work load is too high, and sharing data will add to the already high work load.
- Protection of the privacy of research subjects is of huge concern for some researchers.
- Researchers are sometimes bound by funder contract requirements, which are not necessarily clear on how the data can and should be curated.

Strengths	Well-established & connected OD/OS community | trust in ASSAf | buy-in from NRENs | AfricaConnect bandwidth & connectivity | numerous data-intensive research initiatives | 12 OS/OP declarations & agreements endorsed | 200 OA journals | 174 OA institutional repositories | 24 OA/OS policies | 63+ data repositories | SKA countries | HPC Ecosystem initiative | NICIS approach | SADC Cyberinfrastructure Framework | 10 countries with HPC facilities | SADC Strategic Plan on Science, Technology and Innovation | AOSTI (UN) initiative | online Open Access Open Science/Open Data training | CODATA-RDA workshops | Carpentry training	**Weaknesses** Low implementation of IP & STI policies | data not curated/accessible | data repositories not interoperable | data repositories not registered with re3data.org | 1 data repository have CoreTrustSeal | second-class status of African researchers | data hosted on global platforms | lack of awareness of what is researched on continent, causing duplication | NRENs not operational | low level of Cloud readiness among NRENs | lack of NREN policies & legal recognition | low ICT infrastructure budgets at research institutions | data science training not part of curricula at training institutions, not regulated | building & retaining pipeline of ICT talent challenging | lack of data science skills | obsolete computer infrastructure | lack of incentivising research, data sharing | limited access to research grants | expense of data curation not covered through grants | low awareness around IP | fears experienced by researchers | lack of trust | silo culture among researchers | data sharing is time consuming | low understanding of online licenses | protection of privacy, adhering to ethics | limits because of funder requirements | low awareness re OS among governments | policies take time
Opportunities	AOSP federated approach | AOSP stakeholder network | support for AOSP | integrate OS policy as part of STI policy, through AOSTI (UN) | international interest & alignment with EOSC etc | increased need for collaboration | high commitment from Botswana, Ethiopia, Kenya, Senegal, SA, Tanzania, Uganda – champions | OS policies in Botswana, Madagascar, Mauritius, SA, Uganda | AfricaConnect3 | SADC Cyberinfrastructure roadmap as template | existing curricula at universities presenting data science training | training by AAU, EIFL, CODATA, RDA, Carpentries, others | focus on SDG priority disciplines | utilise open source software | alignment with Africa Consolidated Science and Technology Plan for Action, Agenda 2063, UNECA | progress re OA and repositories (incl. data) | capitalise on global movement for open government data (AfDB) | data repatriation efforts | established communities as stakeholders e.g. Academies, SGCI, Ministries in STI, WIPO | international funder requirements | SGCI statement on OS | data as evidence to contribute to trustedness/profile of African research | online OD/OS courses | data-driven policies in Africa	**Threats** Vastness, many countries in Africa not well connected | data infrastructure not sustainable | low investment in ICT infrastructure | low investment in R&D, HD | priorities differ among countries | 10/54 countries experience conflict | 22/54 not completely free | 6/54 have corruption higher than 50/100 | 8/54 have infrastructure development higher than 50/100 | 20/54 applied Internet censorship | 24/54 have low HDI | 25/54 have medium HDI | none in HDI | dependency on international funding | low number of researchers in Africa | research output not well curated | lack of policies (STI, ICT, IP) | lack of accountability | lack of speed and implementation | complex socio-economic-political status | monopolies of telecoms | unaffordability of Internet | power outages | silos of stakeholders | lack of skills | lack of sustainability built into projects | fake news, fake research, fake data | IPR not well managed

Table 7. Strengths, Weaknesses, Opportunities and Threats (SWOT-analysis)

The identified deficits can be addressed on a Pan-African scale, as explained in The Future of Science and Science of the Future: Vision and Strategy for the African Open Science Platform strategy. A federated African Open Science Platform (AOSP) will not only encourage more collaboration among researchers in addressing the SDGs, but it will also

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

benefit the many stakeholders identified as part of the research process. For AOSP to be sustainable, commitment from African governments is needed. Too often – when projects funded from outside Africa come to an end, there are low levels of contingency, resulting in the initiatives gradually coming to a halt. This can be prevented if governments take ownership in the form of policies, through creating ICT infrastructure environments which will be conducive for science and data sharing, incentivise researchers for conducting research and sharing data, and lastly – integrate data science and data literacy across all curricula.

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

APPENDIX 1 – DISCIPLINE-SPECIFIC DATA INITIATIVES

Table 8. Data-intensive African research initiatives and repositories

Below a list of repositories that are hosting publicly accessible data sets related to the SDGs, organised in disciplines.

AGRICULTURE		
AfricaRice	10	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Gambia, Guinea, Mali, Nigeria, Senegal, Tanzania
Agricultural Research for Development (CIRAD)	37	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cabo Verde, Central African Republic, Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea Bissau, Kenya, Liberia, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, São Tomé & Principe, Tanzania, Togo, Uganda, Zambia, Zimbabwe
Arid and Semi-Arid Lands Knowledge Hub Platform (ASAL K-Hub)	1	Kenya
CountrySTAT Food and Agricultural Data Network	26	Angola, Benin, Burkina Faso, Burundi, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo, Ethiopia, Gabon, Gambia, Ghana, Guinea-Bissau, Kenya, Madagascar, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Zambia
FAOSTAT – Food and Agriculture Organization (FAO)	54	Africa
Jomo Kenyatta University of Agriculture and Technology (JKUAT)	1	Kenya
Kenya Agricultural Information Resource Centre (KAiNeT)	1	Kenya

	Regional Centre for Mapping of Resources for Development (RCMRD)	1	Kenya
	CSIRSpace (Institutional Repository of the Council for Scientific and Industrial Research Ghana)	1	Ghana

HEALTH		
Data Science and Engineering Laboratory (dLab)	1	Tanzania
H3Africa – Human Heredity & Health in Africa	15	Botswana, Egypt, Ghana, Kenya, Malawi, Morocco, Mali, Mauritius, Niger, Nigeria, South Africa, Sudan, Tanzania, Tunisia, Uganda
Africa Health Research Institute (AHRI)	1	South Africa
African Population and Health Research Centre (APHRC)	1	Kenya
Global Health Data Exchange (GHDx)	16	Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, Somalia, South Sudan, Sudan, Tanzania, Uganda, Zambia
International Network for the Demographic Evaluation of Populations and Their Health (INDEPTH)	12	Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Uganda
World Health Organisation (WHO) Regional Office for Africa	47	Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cabo Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Eritrea, eSwatini Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, 2Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, South Sudan, Togo, Uganda, Tanzania, Zambia, Zimbabwe
MalariaGEN	16	Benin, Burkina Faso, Cameroon, Democratic Republic of the Congo, Ethiopia, Ghana, Guinea, Kenya, Madagascar, Malawi, Mali, Nigeria, Senegal, Sudan, Tanzania, Uganda

CLIMATOLOGY		
Green Growth Knowledge Platform (GGKP)	54	Africa
South African Environmental Observation Network (SAEON)	1	South Africa
RESILIENCE ATLAS	5	Ethiopia, Kenya, Madagascar, Tanzania, Uganda
West Africa Science Service Centre on Climate Change and Adapted Land Use (WASCAL)	10	Benin, Burkina Faso, Gambia, Ghana, Côte d'Ivoire, Mali, Niger, Nigeria, Senegal, Togo

OCEANOGRAPHY		
African Register of Marine Species (AfReMaS)	34	Algeria, Angola, Benin, Cabo Verde, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Libya, Mauritania, Morocco, Mozambique, Namibia, Nigeria, Republic of the Congo, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Tunisia
International Oceanographic Data and Information Exchange (IODE) by the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO)	54	Africa
Ocean Data and Information Network for Africa (ODINAFRICA)	26	Angola, Benin, Cameroon, Comoros, Congo Brazzaville, Côte d'Ivoire, Democratic Republic of the Congo, Egypt, Gabon, Ghana, Guinea, Kenya, Madagascar, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Nigeria, 20. Senegal, Seychelles, South Africa, Sudan, Tanzania, Togo, Tunisia
South African Institute for Aquatic Biodiversity (SAIAB)	1	South Africa

BIODIVERSITY		
African plants – A Photo Guide	53	All African countries (excluding Madagascar)
AQUASTAT database	19	Algeria, Burkina Faso, Egypt, Ethiopia, Kenya, Libya, Madagascar, Mali, Morocco, Mozambique, Niger, Nigeria, South Africa, South Sudan, Sudan, Tanzania, Tunisia, Uganda, Zimbabwe
Biodiversity GIS (BGIS) – SANBI	1	South Africa
Botanical Database of Southern Africa (BODATSA) – SANBI	1	South Africa
Global Biodiversity Information Facility (GBIF)	18	Benin, Central African Republic, Democratic Republic of the Congo, Ghana, Guinea, Kenya, Madagascar, Malawi, Mali, Mauritania, Niger, Nigeria, South Africa, 1South Sudan, Tanzania, Togo, Uganda, Zimbabwe
Reseau de la Biodiversité de Madagascar (ReBioMa)	1	Madagascar
Protected Planet	1	Kenya
West African Plants	16	Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo (West Africa excluding Madagascar)
West African Vegetation	12	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo, Ghana, Kenya, Mali, Senegal, Niger, Nigeria, Uganda
World Agroforestry Centre (ICRAF)	6	Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Malawi
GEOSCIENCES		
African Coastal Marine Atlas (ACMA) – Ocean Data and Information Network for Africa (ODINAFRICA)	26	Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Côte d'Ivoire, Democratic Republic of the

		Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, eSwatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho
Centre for Remote Sensing and Geographic Information Systems (CERSGIS)	1	Ghana
CGIAR Consortium for Spatial Information (CGIAR-CSI)	54	Africa
Botswana Geoscience Portal	1	Botswana
GeoTerraImage	16	Angola, Botswana, Comoros, Democratic Republic of Congo, eSwatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia, Zimbabwe (SADC)
Global Sea Level Observing System (GLOSS)	54	Africa
Malawi Spatial Data Platform (MASDAP)	1	Malawi
NARSSGeoPortal	1	Egypt
National Geo-Spatial Information (NGI)	1	South Africa
Ocean Biogeographic Information System (OBIS)	54	Africa
SERVIR (NASA)	33	Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Chad, Côte d'Ivoire, Comoros, eSwatini, Ethiopia, Gambia, Guinea, Guinea Bissau, Kenya, Lesotho, Malawi, Mali, Mauritania, Mauritius, Namibia, Niger, Rwanda, Senegal, Seychelles, Somali, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe
South African Department of Environmental Affairs, Geographic Information System (GIS) Data portal	1	South Africa
South African Department of Rural Development and Land Reform Spatial Data Infrastructure (SASDI)	1	South Africa

BaseGeo	1	Senegal
METEOROLOGY		
African Monsoon Multidisciplinary Analysis – Coupling the Tropical Atmosphere and the Hydrological Cycle (AMMA-CATCH)	8	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Madagascar, Mali, Niger, Nigeria
Experimental Tropical Watersheds (BVET)	1	Cameroon
Niger Basin Authority	1	Niger
Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL)	1	Angola, Botswana, Namibia, South Africa, Zambia
Climate Databank - South African Weather Service (SAWS)	1	South Africa
LAW		
OHADA (Organisation for the Harmonization of Corporate Law in Africa)	17	Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Comoros, Côte d'Ivoire, Democratic Republic of Congo, Equatorial Guinea, Gabon, Guinea, Guinea-Bissau, Mali, Niger, Republic of the Congo, Senegal, Togo
INTERDISCIPLINARY		
DICAMES (Digital archive of the African and Malagasy Council for Higher Education) (Francophone focus)	6	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Niger, Senegal

APPENDIX 2 – AFRICAN SUPPORT FOR INTERNATIONAL STATEMENTS, DECLARATIONS AND INITIATIVES

A number of calls in support of Open Science in its broadest form, including Open Access to scholarly publications, Open Educational Resources, and Open Data, have been issued over the past 17 years. We summarise in Table 8 below the engagement of African states with a number of major initiatives.

2002	**Budapest Open Access Initiative** The Budapest Open Access Initiative is an international effort to make research articles in all academic fields freely available on the Internet.	**38** organisational signatories from Algeria (2), Botswana, Côte d'Ivoire, Egypt (3), Ghana (2), Kenya, Lesotho, Liberia, Mali, Morocco, Namibia, Nigeria (12), Senegal (3), Somalia (2), South Africa (3), Tunisia, Zimbabwe
2003	**Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities** The Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities is an international statement on Open Access and access to knowledge.	**51** organisational signatories from the African continent
2003	**Bethesda Statement on Open Access Publishing** Statement of principles on progressing greater Open Access to published results of scholarly research.	**0** no African participants
2005	**Salvador Declaration on Open Access** Requesting a commitment to equity in relation to publicly funded research through Open Access; publication cost; support for repository services; and the promotion of research from the developing world in the worldwide body of knowledge.	
2008	**Cape Town Open Education Declaration** Initiative to accelerate efforts to promote open resources, technology and teaching practices in education.	**56** organisational signatories from Egypt, Kenya (5), Namibia, Nigeria (3), Senegal, South Africa (40), Sudan, Uganda (2), Zimbabwe (2)
2014	**The Hague Declaration** The Hague Declaration aims to foster agreement about how to best enable access to facts, data and ideas for knowledge discovery in the Digital Age.	**7** organisational signatories from Africa Governance Institute, African Institute for Economic Development and Planning, African Minds, Centre for Information Policy in Africa, Gaborone Technical College (Botswana), Library and Information Association of SA (LIASA), University of Bejaia (Algeria)
2014	**The Principle of Universality of Science and Academic Freedom** According to ISC the principle pertains to academic freedom, emphasises equity and non-discrimination in the international	**28** African members

Please cite as follows: Academy of Science of South Africa (2019), African Open Science Platform - *Landscape Study*. doi: http://dx.doi.org/10.17159/assaf.2019/0047

	practice of science, and explicitly recognises incumbent responsibilities.	
2015	**Cape Town Declaration** Aim is to deliberate on the status of libraries on the African continent and the progress required to meet the global sustainable development goals.	13 country signatories from Angola, Burkina Faso, Cape Verde, Côte d'Ivoire, eSwatini , Lesotho, Guinea, Madagascar, Malawi, Mozambique, Nigeria, South Africa, South Sudan
2015	**Nairobi Data Sharing Principles** These Principles support publicly-funded data and information as a public good.	
2015	**Open Data in a Big Data World Accord** With the purpose to articulate the views of the global scientific community on international matters of policy for science and to promote appropriate actions.	No data available
2016	**Dakar Declaration on Open Science in Africa (Sci-GaIA)** The Sci-GaIA initiative were set to aim at creating a sustainable foundation of educational materials and procedures for the development and management of Science Gateways and e–Infrastructures in Africa and beyond.	12 signatories from the Arab States Research and Education Network (ASREN); West and Central African Research and Education Network (WACREN) and Côte d'Ivoire; Ghana (2); Mali; Nigeria (3); Tanzania; Togo; Uganda
2017	**OA2020** Expression of interest in the large-scale implementation of Open Access to scholarly journals.	13 organisational signatories from Benin, Cameroon, Kenya (2), Nigeria (4), South Africa (4), Uganda
2018	**IDW2018 Gaborone Statement** Expression of interest in advancing Open Data princinples adoption, through the Botswana Open Data Open Science Forum, RDA, CODATA, WDS, AOSP	No data available
2019	**SGCI 2018 Statement** Commitment in steering the dialogue around the social and economic impact agenda, and positively influencing outcomes by contributing to science policy development and designing appropriate funding instruments that promote the full continuum of research.	16 participating Science Granting Councils from Botswana, Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mozambique, Namibia, Rwanda, Senegal, South Africa, Tanzania, Uganda, Zambia, Zimbabwe

Table 9. Summary of the most important statements and declarations requiring signatory support

BIBLIOGRAPHY

African Union African Observatory of Science Technology and Innovation. (2014). *Assessment of Scientific Production in the African Union, 2005–2010*. url: http://aosti.org/index.php/component/content/article/88-reports/133-the-state-of-scientific-production-in-the-african-union?Itemid=437

Alliance for Affordable Internet. 2017. *Affordability Report*. Washington DC. url: https://a4ai.org/

Bédécarrats, F., Cling, J. and Roubaud, F. (2016). The Data Revolution and Statistical Challenges in Africa: Introduction to the Special Report. *Afrique contemporaine*, 258(2), p.9. doi: 10.3917/afco.258.0009

Belhamel, K. (2016). *Open Access Journals Strategy in Algeria*. url: https://blog.doaj.org/2016/10/06/open-access-journals-strategy-in-algeria/

Bezuidenhout, L. (2019). *Incentivizing Data Sharing within African Academia*. url: https://drive.google.com/file/d/1qV7Bu2MGetCTbGw2d2yPn3jzE3P8-b6P/view?usp=sharing

Bezuidenhout, L., Kelly, A.H., Leonelli, S. and Rappert, B. (2017). '$100 Is Not Much To You': Open Science and Neglected Accessibilities for Scientific Research in Africa. *Critical Public Health* 27 (1). doi: https://doi.org/10.1080/09581596.2016.1252832

Bezuidenhout, L. (2013). Moving Life Science Ethics Debates Beyond National Borders: Some Empirical Observations. *Science and Engineering Ethics* 20(2): 445-67. doi: https://doi.org/10.1007/s11948-013-9468-x

Bezuidenhout, L. (2015). Ethics in the Minutiae: Examining the Role of the Physical Laboratory Environment in Ethical Discourse. *Science and Engineering Ethics* 21 (1): 51–73. doi: 10.1007/s11948-013-9506-8

Bezuidenhout, L., Leonelli, S., Kelly, A.H. and Rappert. (2017). Beyond the Digital Divide: Towards a Situated Approach to Open Data. *Science and Public Policy* 44 (4): 464–75. doi: https://doi.org/10.1093/scipol/scw036

Bezuidenhout, L., Rappert, B., Leonelli, S. and Kelly, A.H. (2016). *Beyond the Digital Divide: Sharing Research Data across Developing and Developed Countries.* doi: http://doi.org/10.6084/m9.figshare.3203809.v1

Boulton, G. & Hodson, S. (2018*). The Future of Science and Science of the Future: Vision and Strategy for the African Open Science Platform (v02)*. doi: http://doi.org/10.5281/zenodo.2222418

Economic Commission for Africa. 2017. *Towards Improved Access to Broadband in Africa*. Addis Ababa. url: https://www.uneca.org/sites/default/files/PublicationFiles/towards_improved_access_to_broadband_inafrica.pdf

Ferguson, Liz. (2014). *How and Why Researchers Share Data (and Why They Don't)*. url: https://www.wiley.com/network/researchers/licensing-and-open-access/how-and-why-researchers-share-data-and-why-they-dont

Foley, M. (2016). *The Role and Status of National Research and Education Networks (NRENs) in Africa*. url: http://documents.worldbank.org/curated/en/233231488314835003/pdf/113114-NRENSinAfrica-SABER-ICTno05.pdf

Galagan, D. and Looijen, M. (2015). *National Research and Education Networks: Analysis of Management Issues*. url: http://www.isoc.org/isoc/conferences/inet/99/proceedings/3h/3h_1.htm

Harle, Jonathan. 2010. *Growing Knowledge : Access to Research in East and Southern African Universities*. url: https://www.researchgate.net/publication/289540042_Growing_knowledge_access_to_research_in_east_and_southern_African_universities

Heymann, D. L., Liu, J. and Lillywhite, L. (2016). Partnerships, Not Parachutists, for Zika Research. *New England Journal of Medicine* 374 (16). Massachusetts Medical Society: 1504–5. doi: 10.1056/NEJMp1602278

International Council for Science, InterAcademy Partnership, International Social Science Council, and World Academy of Science. (2015). *Open Data in a Big Data World*. 56, Paris. url: https://council.science/publications/open-data-in-a-big-data-world

Kaye, J., Heeney, C., Hawkins, N., and De Vries, J. (2009). *Data Sharing in Genomics — Re-Shaping Scientific Practice*. *Nat Rev Genet*. 2009 May; 10(5): 331–335. doi: 10.1038/nrg2573

Kaye, J., Sharon F. T., Juengst, E., Coy, S., Harris, J.R., Chalmers, D., Dove, E.S. et al. (2018). Including All Voices in International Data-Sharing Governance. *Human Genomics* 12 (1): 13. doi: 10.1186/s40246-018-0143-9.

Knoppers, B.M., Harris, J.R., Tassé, A.M., Budin-ljøsne, I., Kaye, J. and Deschênes, M. (2011). Towards a Data Sharing Code of Conduct for International Genomic Research, *Genome Medicine* 3:46. doi: https://doi.org/10.1186/gm262

Leonelli, S. (2017). *Mutual Learning Exercise: Open Science - Altmetrics and Rewards*. Brussels.

Leonelli, S., Spichtinger, D. and Prainsack, B. (2013). Sticks AND Carrots: Incentives for a Meaningful Implementation of OS Guidelines. *Geo*. 2015 Jan-Jun; 2(1): 12–16. doi: 10.1002/geo2.2

Marcus, A. (2015). *Data and the fourth industrial revolution*. url: https://www.weforum.org/agenda/2015/12/data-and-the-fourth-industrial-revolution/

OECD. (2007). *OECD Principles and Guidelines for Access to Research Data from Public Funding*. url: http://www.oecd.org/sti/inno/38500813.pdf

Pillay, T. (2018). The EU's GDPR and some African data protection laws differ significantly. *Business Day*. url: https://www.businesslive.co.za/bd/opinion/2018-05-31-the-eus-gdpr-and-some-african-data-protection-laws-differ-significantly/

SA Dept. of Science and Technology. (2019). *White Paper on Science, Technology and Innovation*. url: https://www.dst.gov.za/images/2019/FINAL-White-Paper-to-Cabinet_11-March-2019.pdf

Serwadda, D., Ndebele, P., Grabowski, M., Bajunirwe, F. and Wanyenze, R. (2018). Open Data sharing and the Global South - Who benefits? *Science*, 359(6376), pp.642-643. doi: 10.1126/science.aap8395

Suber, P. and Shieber, S. (2019). *Good practices for university open-access policies*. url: https://cyber.harvard.edu/hoap/Good_practices_for_university_open-access_policies

Tenopir, C., Allard, S., Douglass, K., Aydinoglu, A.U., Wu, L., Read, E., Manoff, M. and Frame, M. (2011). Data Sharing by Scientists: Practices and Perceptions. *PloS One* 6 (6): e21101. doi: https://doi.org/10.1371/journal.pone.0021101

United Nations. (2018). *Human Development Report 2018*. url: http://hdr.undp.org/en/2018-update

United Nations Economic Commission for Africa. (2018). *Sustainable Development Report*. url: https://www.uneca.org/publications/2018-africa-sustainable-development-report

Vermeir, K., Leonelli, S., Bin Tariq, A.S., Sojinu, S.O., Ocloo, A., Khan, M.A.I. and Bezuidenhout, L. (2018). *Global Access to Research Software: The Forgotten Pillar of Open Science Implementation*. url: https://globalyoungacademy.net/wp-content/uploads/2018/03/18013_GYA_Report_GARS-Web.pdf

Wilkinson, M.D. et al. (2016). The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*. doi: 10.1038/sdata.2016.18