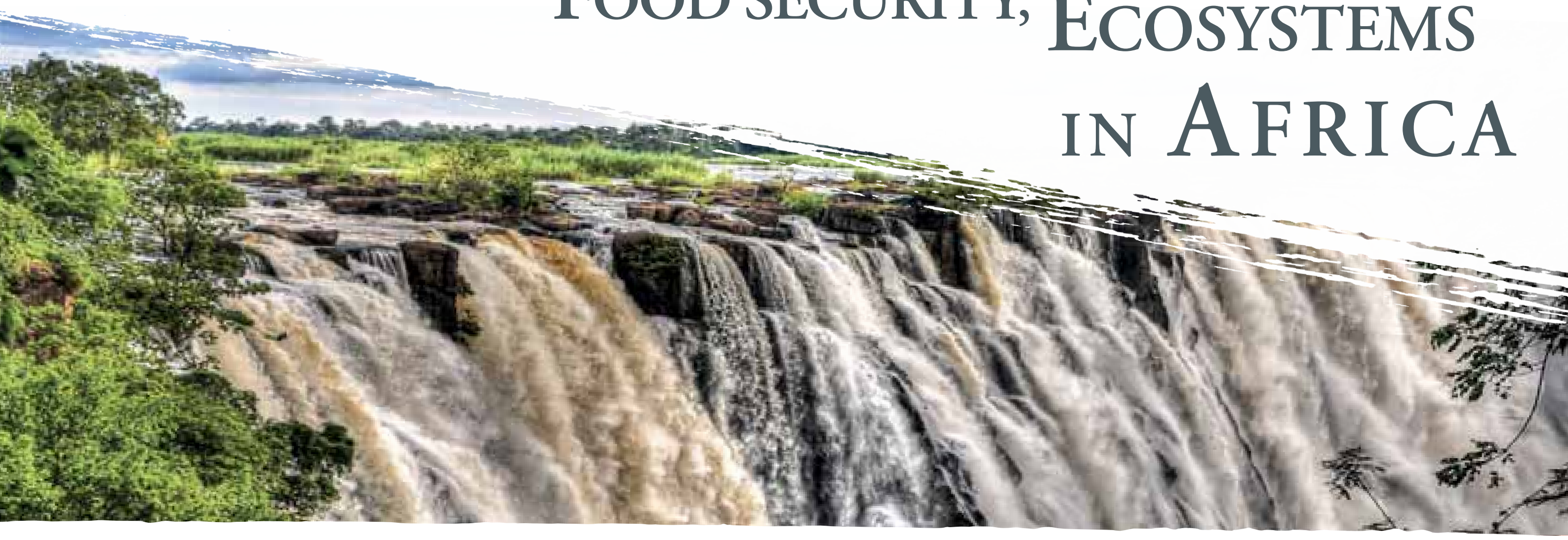
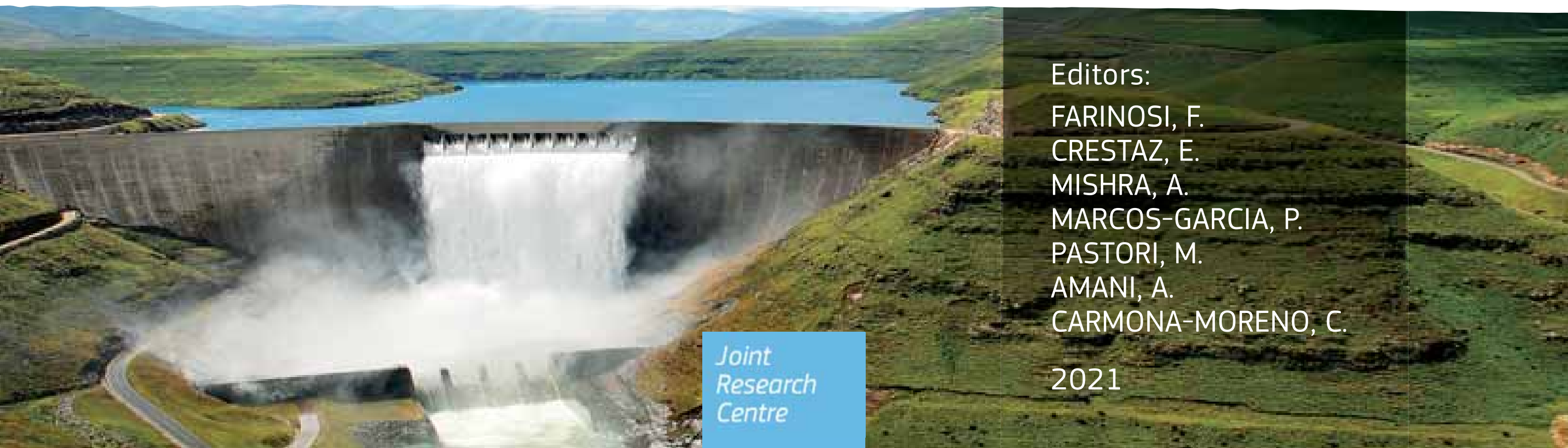
European Commission

SCIENCE BEHIND THE DEBATE

Water, Energy, Food security, Ecosystems in Africa





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JRC124436 - WEFE Nexus perspectives in Africa
JRC124454 - Human Capacity Development in the Water Sector in Africa
JRC124435 - The Water and Energy Nexus in Africa
JRC121584 - Status of Geothermal Industry in East African countries
JRC124455 - Framing the state-of-the-art in digital tools use for sustainable groundwater resource management in Africa
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NILE BASIN INITIATIVE
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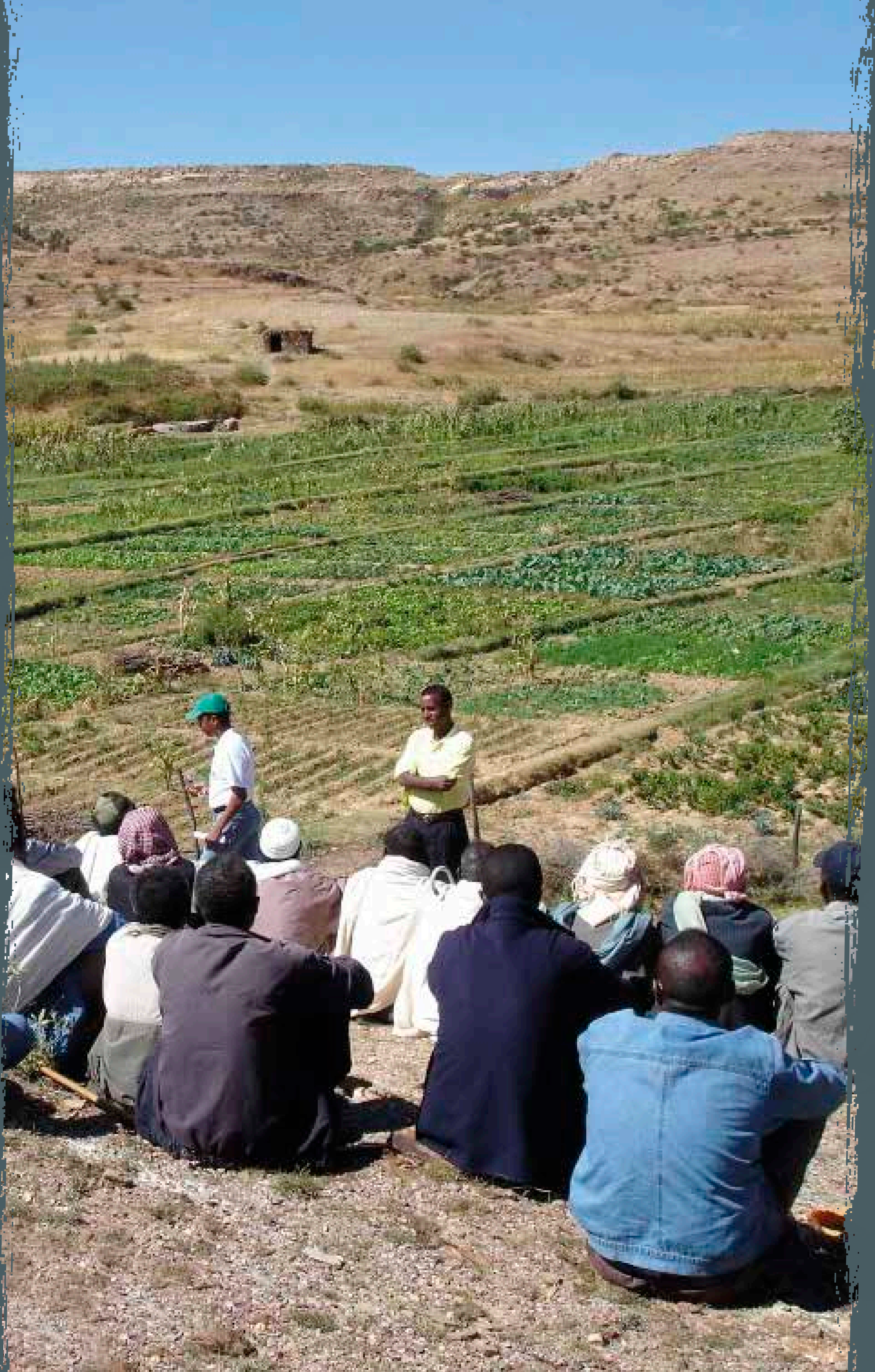

FOREWORD

Although there are water resource problems in all regions of the world, no region is more affected than sub-Saharan Africa. Inadequate infrastructures, including deficits in development and digitalisation, are among the main reasons for its susceptibility and vulnerability to water-related issues. Accessibility to water in the African continent is crucial, because current resources (human, financial and infrastructural) are generally insufficient to ensure adequate and equitable water distribution and management.

Good access to water resources is vital to many dimensions of development. It contributes not only to economic growth but also to the well-being of African populations and, consequently, to improving their political stability. There is a paradox that is particularly evident in Africa, whereby the precariousness of the poorest economies often hinders the implementation of medium- and long-term development programmes, thus preventing the creation of the robust infrastructure that is necessary for economic growth. The spread of infectious diseases in regions with limited water access[1] also hampers development and social welfare. For example, malaria costs Africa more than US$12 billion a year, slowing its economic growth by 1.3% annually[2].

Sustainable agriculture, the most important economic activity in most African countries, is another water-related issue. It is still 96% rain-fed and provides employment for about two-thirds of the continent's working population. Extreme climate variability in sub-Saharan Africa greatly affects agricultural productivity, undermining both food security and economic activity. Better-adapted and better-targeted policies on water resources management would improve the efficiency of water use and help to reduce the volatility of African economies.

Management and policies must also include both surface water and groundwater storage and their interactions, since they are essential to the resilience of African agriculture and the continent's energy development. However, the environmental impacts of water infrastructure must be appropriately assessed. While hydropower constitutes an attractive clean energy source for industrial and economic development at regional level (due to its relative insensitivity to fluctuations in global oil and gas prices), its availability is also highly volatile due to climate change[3]. Some African countries have significant resources with renewable energy potential (photovoltaic, bioenergy, wind and – along the Eastern Africa Rift Valley – geothermal energy) that could be exploited more actively, leading to benefits in terms of low greenhouse gases emissions and low sensitivity to climate change.

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All these aspects briefly synthesise how water, energy, agriculture, food security and ecosystems (WEFE) are closely interlinked sectors that are essential for sustainable development. An integrated understanding of the multi-sectoral issues of WEFE, the identification of priorities, their interactions and trade-offs and the joint development of knowledge and human capacities is the basis for informed, responsible and sustainable decision-making.

This work is the result of the past four years of collaboration, supported by the Directorate-General for International Partnership (DG INTPA) and jointly coordinated by the Joint Research Centre (JRC) of the European Commission and UNESCO-IHP working with the AUDA-NEPAD Centres of Excellence in Water Sciences, the Executive Secretariat of African Ministers' Council on Water (AMCOW), the Regional Economic Communities (ECOWAS, IGAD, SADC) and the authorities of the African basins of Niger, Nile, Senegal and Zambezi.

This report presents the findings, conclusions and recommendations arising from the various activities on the WEFE Nexus in Africa. More than 80 deliverables, including technical reports, good practice manuals, databases, human capacity development products and policy briefs have been produced. This document demonstrates how long-term collaboration between research and policy institutions contributes to sustainable development through information sharing, data and joint knowledge development.

1 WHO - World Health Organization Regional Office for Africa, 2019. Of the estimated 10 million deaths per year resulting from infectious diseases, the majority occur in Africa.

2 "Focusing on improved water and sanitation for health". Bartram J, Lewis K, Lenton R, Wright A. The Lancet. 2005;365:810–812.

3 ECOFIN Agency. June 2020. Africa's hydropower segment needs to increase its resilience to climate change. Dams currently provide 17% of the continent's electricity, and 23% by 2040. Climate variability represents 3% of an electricity loss per year.

ACKNOWLEDGEMENT

The editors would like to acknowledge the efforts of all the institutions, scientific and technical staff who have collaborated on this work over the past years. This is evidence of a pragmatic approach to Science and Water Diplomacy, based on close and long-term collaboration between institutions, which tackles concrete and real problems in order to work towards the Sustainable Development Goals.

We would like to thank the DG International Partnership (INTPA), DG JRC, UNESCO, the African Ministers' Council on Water (AMCOW) and AUDA-NEPAD for envisioning the need for this collaboration between research institutions, which has been ongoing since 2009, and for understanding that it is only by working together over the long term that challenges of an often complex nature can be tackled and resolved.

SUMMARY

This report summarizes the main findings of the different activities that the Joint Research Centre of the European Commission and the different partner institutions are conducting within the framework of the Water Energy Food Ecosystem nexus analysis in sub-Saharan Africa.

After introducing the topic, the priorities and needs identified by the African institutions, and illustrating the response of the European Commission and its partners, the report illustrates the past and current state of the WEFE nexus dynamics in the region. It identifies the main challenges that the interconnected sectors within the nexus are likely to face in the coming decades. In particular, the region is expected to be strongly affected by global climate change affecting African regions unevenly and by rapidly changing socio-economic and demographic dynamics. These topics are analysed in a general way for the sub-Saharan macro-region, but also through specific case studies carried out jointly with the AUDA-NEPAD African Centres of Excellence on Water Science and Technology, in collaboration with AMCOW, AUDA-NEPAD, regional economic committees and river basin authorities. Concretely, WEFE nexus analyses are presented for the Senegal, Blue Nile and Lake Victoria, Zambezi, and Niger Basins, with particular focus on the main challenges related to water management and the application of the WEFE nexus approach. Challenges with regard to integrated water management are thoroughly discussed and then structured in a set of concluding messages, followed by a set of policy recommendations drafted from the interaction between the scientific community and the institutional environment involved in water management across the sub-Saharan African region.

The publication also includes a series of seven factsheets ("The Science Behind the Debate") which deal in more detail with topics of particular relevance in Africa and which complement the technical report.

European Commission

UNESCO
United Nations Educational, Scientific and Cultural Organization

Intergovernmental Hydrological Programme

AUDA-NEPAD

Water Science to support Policy Making in Africa

Headlines

- ✓ **In the African continent, 90% of water resources** are found in **63 transboundary river basins**. By inference, **Water Diplomacy** based on a sound knowledge foundation should be one of the key component to ensuring efficiency, efficacy, equity, inclusiveness and sustainability of the management of water and related resources in Africa.
- ✓ Globally, proper management of the Water sector is hampered by the lack of reliable **knowledge, information and data** on water quantity and quality. In Africa, the Water sector should **integrate local and traditional knowledge** to fill the gap in existing knowledge, information and data needed for evidence-based policymaking. There is also a growing need for a nexus approach as a way to tackle cross-sectoral issues, trade-offs and stimulate interdisciplinary dialogues.
- ✓ There are **significant capacity gaps** (e.g. researchers, professionals and technicians) and regional differences in the priorities of capacity needs. The extent and type of these gaps need to be assessed in detail and then addressed. The International Water Association (IWA) survey in ten (10) developing countries in Africa and Asia estimated that in 2014 over **780,000 sector staff were needed** to achieve the Millennium Development Goals (MDGs). These aspirations need to be updated to address the Sustainable Development Goals (SDGs).
- ✓ **Discrepancies** exist between the **Water Sector needs** and what **educational institutions are able to provide** in terms of knowledge, skills and competences.
- ✓ **Education content gaps limit job opportunities** in the Water Sector, contributing to migration of personnel to other sectors or geographical areas for better opportunities. These gaps often overshadow the central role of women in water management.
- ✓ The **UA-NEPAD Centres of Excellence** on Water Science are **mapping skill gaps** at the national level **and proposing updated curricula** to 1) improve skills by meeting the industry's qualification and competency requirements; 2) provide hands-on training to institutional, professional and technical staff to enable them to adapt to sector/technical changes; and, 3) develop new responsive courses tailored to the actual needs of the sector.

Policy Context

The **2020 Global Risks Report**[1] of the World Economic Forum ranks Water Crises and other water related issues among the top five global risks in terms of impact since 2015. This risk is aggravated by climate change and population growth as they impact the quantity and quality of available freshwater, leading to adverse effects on human health and/or economic activity. SDG 6 aims to ensure availability and sustainable management of water and sanitation for all – water is crucial for the sustainability and development of the livelihood of low-income households and developing economies in general. Similarly, sustainable access to clean water and sanitation, as well as water resources management, play an important role in the rest of SDGs, especially 1, 2, 3, 4, 5, 7, 11, 12, 13, 15 and 16. The linkages and interactions between the SDGs require a concerted effort and collaboration among all relevant actors at all levels to ensure that by 2030 no one is left behind.

Water is essential for economic and social development. Freshwater availability is a key determining factor in efforts to ensure food and energy security as well as for increasing industrial production – thus underpinning jobs and employment in a wide range of sectors. The quality of freshwater ecosystems has a direct impact on the well-being and productivity of human populations and, thus, on the sustainability of national economic growth and development. Access to clean water is fundamental to the health of human communities[2]. Secure and equitable access to safe water and sanitation and good water management practices contribute directly towards achieving gender equality and access to education, health and well-being.

Current political debate is increasingly engaging in the future availability of freshwater in a changing world. More than 40% of the population of Sub-Saharan Africa does not have sufficient access to safe water and sanitation. **Access to water and sanitation,** and **renewable water resources per capita in Africa** are spatially **highly unequal and variable** (Fig. 1). Eight out of ten people who still lack basic services live in rural areas, and almost half of them live in Least Developed Countries[3].

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[1] Water Economic Forum 2020 Global Risk Report

[2] FAO 2012. Nature and Faune. Enhancing natural resources management for food security in Africa Volume 27, Issue 1, pg 3

[3] 5.3 billion people of the world population used safely managed services. An additional 1.4 billion used at least basic services. 206 million people used limited services, 435 million used unimproved sources, and 144 million still used surface water (Progress on household drinking water, sanitation and hygiene 2000-2017. Special focus on inequalities. New York: UNICEF and WHO Joint Monitoring Program Report, 2019)

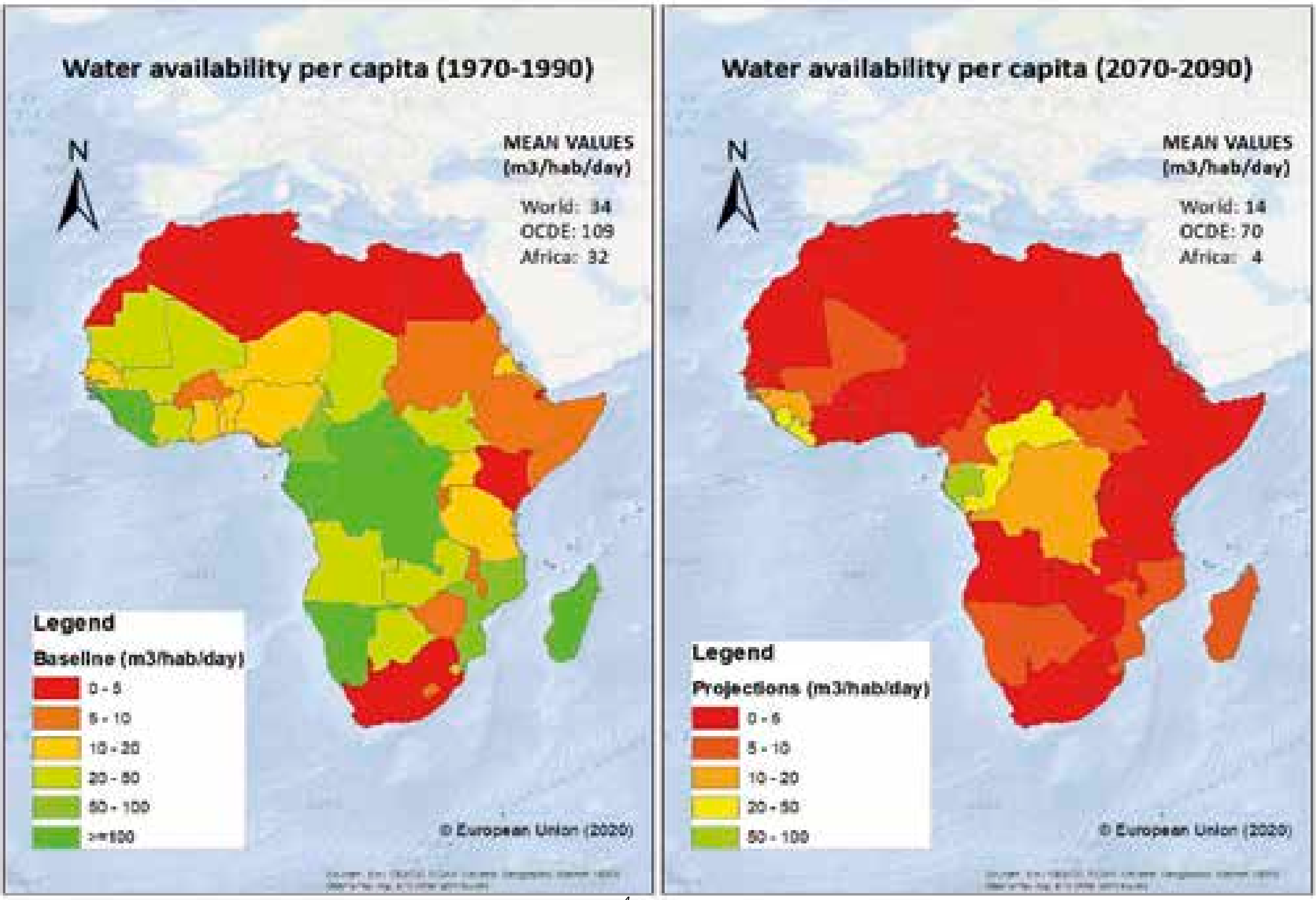

Figure 1. *Total Renewable Water Resources per capita and projections*[4].

More than **90% of Africa's water resources** fall within **63 river basin catchments shared by multiple countries** (Fig. 2). In Africa, there are many governance mechanisms for water management from the national and regional levels (basin organisations and regional economic communities) to the continental level (African Ministers' Council on Water – AMCOW). **Water Diplomacy** emerges as a suitable tool for strengthening peace and sustainability addressing issues and challenges in water resources management in Africa, involving negotiations, international and cooperative dialogues that must be based on sound knowledge and informed decisions. The **Science-Policy interface** plays an essential role in fostering water management dialogues on various institutional levels. These dialogues are particularly important in international watercourses, where competition for the allocation of water resources among countries and uses, exacerbated by climate change and population growth, could become a potential source of conflict or an opportunity for cooperation. To illustrate the need for these dialogues, the **African population is forecasted to double by 2050**[5] **increasing the continent's share in the global population from 16% in 2015 to 25% by 2050 and 39% by 2100, which will have a clear impact on access to the resources and the need for development and cooperation (Fig. 1).**

Key Science-Policy Interface Issues.

In general, the role of science as a driver of capacity, knowledge and information development is key to good governance and cooperation initiatives. However, it is also acknowledged (Hodgson, 2010), particularly in the African context, that policy formulation requires more than knowledge derived from scientific evidence to improve the effectiveness of policies. The use of research results in the implementation of SDGs and programmes cannot be a mere technical process[6] and must be driven by a strategic vision of the future. Only policymakers can provide the latter. To overcome these challenges, the United Nation's 2030 Agenda (SDG 17) emphasises the importance of creating science-policy partnerships.

The interface between policy and research is always subject to tensions for several reasons, including, among others, differing rationales and time horizons and subsequently lack of mutual expectations. In particular, in the African context, several "obstacles" have been identified[7][8], including:

1. The **complexity of evidence:** while researchers consider scientific literature an important form of evidence, policymakers rely on practical knowledge from the field and political understanding. Moreover, scientific evidence on the same subject may sometimes be contradictory if different methodologies, perspectives and theoretical principles are used. This leads to mistrust of scientific results by policy makers.

4 FAO, 2020. Projections of future total renewable water resources (TWR) by country for different climate change scenarios available

5 Based on United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2019 Revision

6 Fourie, W., 2018. "Six Barriers that make it difficult for African states to use Research for Policy". The Conversation Africa blog.

7 *Ibidem*, 6.

8 Grimm et al, 2018. The Interface between research and policy making in South Africa: Exploring the institutional framework and practice of an uneasy relationship. Deutsches Institut für Entwicklungspolitik (DIE).

Figure 2*. The Niger River, the third-longest river in Africa has a basin area equivalent to 21% of the area of Europe and 2.6 times the size of the Danube Basin and is shared by 9 sub-Saharan countries.*

2. **The structural underfunding of research:** some research on evidence-based policy interventions can be very costly and incompatible with the African governments' available budgets.
3. **Limited incentives** for applicable and policy–oriented research publications.
4. **Different timeframes** between research and policymaking. It is often the case that long and protracted timeframes for in-depth research activities (including peer-reviewed publication) could not be synchronised with the urgency of policy formulation to address sometimes pressing societal challenges. On the policy side, too, there is a reluctance to reading research papers and technical reports.
5. **Gaps in the education system:** relevant topics in the water sector are not always fully considered or addressed by education system. Therefore, young students are not sufficiently trained to become decision-makers or researchers. They need additional training and experience.
6. **Mistrust between researchers and policymakers** is historically well anchored. From perspective of researchers, policymakers generally lack experience and knowledge to understand cutting-edge research. From the perspective of policymakers, research results need to be contrasted with the reality on the ground, as research end before on-ground implementation. Researchers are not always fully engaged in practical implementation.
7. **Inadequate expectations** regarding the research-policy interface, which are unlikely to be met due to differing agendas, rationales and roles.
8. **Communication** between the two communities is often **irregular and ambiguous**, using vocabularies that are not always appropriate or in common. This can also mean that policymakers may not have access to up-to-date information on research advances and tools, and researchers may not have access to information on relevant challenges considered by the decision-makers.

The Science-Policy Interface: Dynamics of Challenges-Causes-Consequences and Solutions.

These different "obstacles" combine into complex challenges that make the research-policy interface even more difficult to construct. An analysis of these challenges to identify the causes and consequences is necessary in order to come up with recommendations and sustainable and coherent solutions.

1. ***Challenge***: Unknown, growing and very heterogeneous skills gaps across countries in the Water Sector in Africa[9].
Causes: Lack of sector skills analyses, limited resources for capacity development, and limited skill- or competence- based curricula or even absence of relevant water-related curricula in technical, vocational and higher education institutions.
Consequences: Mismatch between competencies and skills required by industry and those offered by capacity building institutions, which limits the usefulness of graduates in the sector. As a result, trained professionals and technicians move to other sectors while the water sector remains understaffed.

***Recommendations and Solutions*: i)** map out the actual gaps in skills and human capacity at the national scale[10]; **ii)** work closely with the private sector and training and education institutions to develop appropriate curricula; **iii)** promote internship opportunities tailored to actual needs in the field; **iv)** create job opportunities in the water sector; **v)** strengthen hubs for developing and sharing knowledge and information between scientific and technical professionals; **vi)** develop a NEXUS approach in education to build more sustainable solutions and give water professionals a broader base for job-seeking; **vii)** Involve local communities in science-policy discussions for the development of the sector in order to integrate traditional and field-based practical knowledge on water resource management, including water consumption, conservation, quality and storage methods. The contribution of women is considered here as an essential input.

2. ***Challenge***: Many of the research tools proving the challenges facing the sector and the interrelationships between sectors are either not used or under-used by policy-makers and water managers. This represents a gap between Water Science and Policy Making that hinders understanding of water-related issues and challenges in order to provide concrete and sustainable solutions.
Causes: 1) Scientists developing tools do not always integrate the institutional, economic and cultural constraints under which policymakers operate; 2) policymakers are often unaware of the availability of relevant scientific research and tools; 3) there is an inconsistency between the timeframes within which scientists/researchers and policymakers operate[11]; and, 4) the limited engagement between researchers and policymakers leads to researchers pursuing topics of fundamentally scientific interest and little immediate relevance/priority to the policymaker.

9 WASH Human Resource Capacity Gaps in 15 Developing Economies. International Water Association, 2014.

10 "There is no blanket approach to capacity development at scale. We need country-by-country tailored solutions." Five solutions to avoid a water sector human resources crisis. IWA Newsletter, September 4, 2016

11 Agricultural Water Management. Proceedings of a Workshop in Tunisia (2007), Chapter: How can scientific research be more effectively integrated into public policy making?

Figure 3. European Development Days – 2019. Water Science and Policy Dialogues: AMCOW – Executive Secretary, DEVCO, JRC, UNESCO, PAWES, AU—NEPAD Centres of Excellence on Water Science.

Consequences: The key role of water as a driver in economic development is often insufficiently understood in many sectors. Water is treated as an assumed precondition. Conversely, the potential adverse effects of economic development on the quantity and quality of water resources are also not systematically recognized and sometimes ignored. Thus, water and the achievement of the objectives of SDG 6 are not high on the economic development policy agenda. There is no clear articulation of water and its interactions with the different sectors to highlight the key role of water in development and the achievement of other SDGs.

Recommendations and Solutions: **i)** Communication *and collaboration are key* to building and strengthening links between Water Scientists and Researchers, Water Practitioners, Policymakers and other key stakeholders on the Policy Makers' agenda; **ii)** Develop and strengthen a common platform for dialogue – a space for communication and exchange – functioning as a Water Think-Tank to address a wide range of topics and set priorities, proposing concrete solutions designed for clearly defined and effective outcomes, e.g., Baseline Studies, Position Papers, Policy Briefs, Action Plans; **iii)** Clarify the assumed catalytic role of water in development for other sectors; **iv)** Government officials and researchers need to engage in co-creation of research to reduce uncertainties, working on more targeted research topics that support country priorities; **v)** Outcomes should be presented to the institutions of both the European Union (EU) and the African Union (AU), including the African Ministers' Council on Water, the Regional Economic Communities (RECs), as well as River and Lake Basin Organisations (R/LBOs) to initiate Policy Declarations (Fig. 3). The next steps would be to downscale and implement these Policy Declarations and target government institutions at national, sub-national and cross-sectorial levels (Fig. 4). **vi)** Researchers should participate more in field projects to contrast research with the ground realities. These actions can provide an impetus for the EU and AU to raise the profile of the water agenda in national regional and international fora.

3. ***Challenge***: The lack of data and knowledge exacerbates the complexity of managing water ecosystems and the uncertainty about the outcomes of choices and decisions made in managing water resources. There are constraints to availability of, and/or access to, data of enough quality and knowledge on: i) water quantity and quality parameters; and, ii) the impact of climate variability and change on water and other natural resources.

Causes: i) reliability and availability of data and research results often not packaged in an accessible (or usable) form for decision makers; ii) insufficient database systems and related Information Communication Technology (ICT) tools, networks and equipment that are openly shared across institutions (or countries in the case of transboundary river basins and aquifers); iii) a lack of adequate networks of hydro-meteorological and gauging stations and necessary maintenance; iv) a looming gap in long-term human competencies, due in part to a lack of smooth handover of skills and capacities, but also due to training gaps of a younger generation of professionals and technicians; v) evidence from research is not often accessible to decision-makers.

Consequences: i) There is a poor (technical and scientific) collection, analysis utilisation, storage, updating and management of data and related information management infrastructure; ii) missed opportunities for knowledge creation and scientific research; iii) difficulties in producing usable long-term datasets; and, v) negative impact on the quality of project identification and formulation.

Recommendations and Solutions: **i)** Create and maintain national, regional and continental hubs for sharing and improving local and traditional knowledge; **ii)** Sharing information and data and monitoring systems at different institutional and inter-institutional scales; **iii)** Research results need to be accessible by summarising and translating complex data in short, and concise policy recommendations for decision-makers with limited time; **iv)** Continuous engagement, promoting partnerships and building trust between researchers and data-responsible authorities such Water Ministries or National Statistics Offices to allow access to data and information; **v)** Orienting curricula to address maintenance for data collection apparatus, consistency of data measurement and data storage; **vi)** Incentivise researchers to produce policy-oriented outputs. Science communication is a key competency that enables translating research results into usable information by policymakers.

Science-Policy Interface: The Way Forward.

EU-AU Institutional Policy. The AU-EU joint Strategic Partnership[12] includes the Development of Knowledge-based Societies: *"Efforts need to be made to address the scientific divide and increase Africa's research capacities"*. In this framework, Africa and the EU stressed their common will to strengthen the collaborative links between African regional and sub-regional partnerships and European partners, and contribute to the sustainability of centres and networks of excellence already established in Africa.

[12] AU-EU joint Strategic Partnership (JAES) is the formal channel through which the European Union and the African continent work together. JAES was adopted by Heads of State and Government at the second EU-Africa Summit in 2007.

Since 2009, the European Commission has supported the implementation of the **AU-NEPAD Centres of Excellence on Water Science**[13] within the wider framework of the AU–EU Strategic Partnership. With the support of the Joint Research Centre of the European Commission, the activities implemented by the AU-NEPAD Water Centres of Excellence are enhancing collaboration between the different actors in the water sector in Africa, improving the scientific and technical capacities of local and regional institutions, and supporting them by providing quality knowledge and evidence to decision-makers of the water sector. Collaboration and coordination between the local/regional technical and scientific institutions are strengthened through regular meetings. This joint effort allows producing reports, databases and models on successful developments at different levels (national, river basin, regional and continental), addressed to AMCOW-Technical Advisers Committee (AMCOW-TAC) (Fig. 5), the African river basin authorities and the regional economic commissions.

The Executive Committee of the African Ministers' Council on Water (AMCOW), in Cairo 2013[14], noted: "the growing human resources shortages to achieve water and sanitation goals in Africa and directs the Secretariat to work with the AUC and **NEPAD Centres of Excellence** to develop a Human Capacity Development Programme aimed at addressing junior professional and technician level capacity challenges in the water sector".

Figure 4*. WEFE-SENEGAL – NEXUS Dialogues*[15].

In late 2017, during the EU-AU Summit in Abidjan, the Heads of State and Government of Member States of AU and EU affirmed the importance of "*Investing in Youth for Accelerated Inclusive Growth and Sustainable Development*". They further noted the necessity of deepening collaboration and exchange in the fields of education, technology development, knowledge, skills and research, in order to cope with the impacts of the fourth industrial revolution through the unlocking of the youth potential. Concretely, the objective was to increase the employability of young people, to set up pathways to facilitate the mobility of entrepreneurs, students and researchers, and to develop better and more flexible mechanisms for regular migration.

The **AU-NEPAD Centres of Excellence programme** is in line with these various points and integrates the priorities of the **New European Consensus on Development** 2017 (**ECD**)[16]:

People: Support sustainable and integrated water management as well as more efficient use of water and water recycling, through a more strategic approach to regional development and integration (**ECD art. 26**).

Planet: Support the conservation and sustainable management and use of natural resources; and improve the governance and capacity building for the sustainable management of natural resources (**ECD art. 44**).

Prosperity: Creating decent jobs for inclusive and sustainable growth (**ECD art. 47**). Public sector investment in research and innovation and cooperation in science and technology will also unlock private sector investment and drive inclusive sustainable growth in developing countries (**ECD art. 49**).

Peace: In the context of peace and stability, revitalise partnerships with qualified regional partners (**ECD art. 68**).

Partnership: The EU and its Member States will make use of different and complementary modalities and modes of aid delivery including twinning, technical assistance and capacity building (**ECD art. 79**). The EU and the AU will work together to promote South-South and triangular cooperation (South-North-South) to facilitate a strong institutional framework of dialogue.

Figure 5*. Meeting of the African Ministers' Council on Water – Technical Advisory Committee (AMCOW-TAC) – 2018.*

Future goals and challenges include **i)** the need to understand patterns of mobility of knowledge, **ii)** identify skills and migration demands in order to develop strategies that can both strengthen the resilience of Africa's Water Sector at the national and transboundary levels, **iii)** open up the sector to provide more employment opportunities, especially for the youth. Part of this understanding is being acquired with the efforts of **AU-NEPAD**

13 ACEWATER Project. "African Centres of Excellence on Water" Project funded by the European Union, coordinated by the Joint Research Centre of the European Commission and implemented in collaboration with UNESCO-IHP.

14 Decisions of the 11th AMCOW Executive Committee of the African Ministers Council on Water (AMCOW). 6th June 2013 in Cairo, Egypt.

15 WEFE-SENEGAL project. Project funded by the European Union, coordinated by the Joint Research Centre of the European Commission and implemented in collaboration with the Italian Cooperation Agency (AICS) to promote cross-sectorial dialogues in the Senegal River Basin.

16 The New European Consensus on Development 2017 (ECD). "Our World, Our Dignity, Our Future". 2-June-2017.

Centres of Excellence on Water Science through the **mapping of skills gaps** at the national scale in 14 African countries with regional synthesis and considering gender aspects. Through the participation of government departments, water utilities, educational institutions and the private sector, the Centres of Excellence are developing frameworks for human capacity development, therefore, implementing the AMCOW EXCO directive of 2013[17] to address human resources shortages and improve the water sector. **Curricula** are being adapted or developed to **1) upgrade skills** by responding to industry skills and competency requirements; **2) provide better hands-on training** for institutional, professional and technical staff to equip them to adapt to sectoral/technical changes; and, **3) develop new responsive courses** to sector needs. **Preliminary results** suggest that there is a greater **need for training of Management and Administration staff** in Eastern Africa compared to Southern and Western Africa. In comparison, there is a greater **need for vocational, technical education and training** in Southern Africa than in Eastern and Western Africa. There is also a greater **need for capacity development on water access and sanitation** in Western and Southern Africa, compared to Eastern Africa. In addition, these activities are augmented with **south-south exchange of students and academics. Engaging with the private sector** can further optimise and extend the sharing of local expertise/resources in Africa for the direct benefit and better career prospects of young professionals to resolve the actual needs of the water sector and other associated sectors (agriculture, energy, infrastructures). The next step would be to scale up these initiatives and roll out similar programmes in other countries given the lessons learnt with the aim of understanding the skills and competencies required to deliver sustainable water management, water supply and sanitation for all.

The AU-NEPAD Network of Water Centres of Excellence is active and the regional networks are growing. The next phase foresees the expansion of the network to include Centres of Excellence in North Africa and strengthening collaboration with the institutes of the Pan-African University.

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[17] Ibidem, 14

SCIENCE BEHIND THE DEBATE

WEFE Nexus perspectives in Africa

Key points

- ✓ The political agenda of the Member States of the African Union sets up ambitious goals to ensure the health and well-being of the population through the transformation of Africa's economy, promoting its competitiveness as well as its environmental sustainability and resilience.
- ✓ The Water, Energy, Food and Ecosystems (WEFE) Nexus approach supports a more integrated and sustainable use of natural resources at all scales. The key principles of WEFE Nexus are: 1) understanding the interdependence of resources within a system across space and time; 2) recognizing the interdependence between water, energy, food and ecosystems; 3) identifying integrated policy solutions to optimise trade-offs and maximise synergies across sectors; 4) ensuring coordination across sectors and stakeholders and; 5) valuing the natural capital of land, water, energy sources and ecosystems. However, although the benefits of applying the WEFE Nexus framework are widely recognised, it is still perceived more as an evolving concept rather than a fully operational approach.
- ✓ Five main priorities have been identified for the African water sector, regarding agriculture and energy: 1) promoting a new narrative on water, to recognise its full potential in the African economy; 2) strengthening the business case for water investments; 3) advocating and promoting water infrastructure development as a means to provide a service (water) to the economy; 4) application of the High Level Panel on Water (HLPW)[1] principles for valuing water and; 5) promoting and facilitating investment led transboundary management and governance of water and environmental resources.
- ✓ The European Union is actively cooperating with the African Union in several policy initiatives framing the demand for the WEFE nexus approach to water development in Africa. The Water, Energy, Food and Ecosystems in Africa (WEFE-Africa) work programme of the Joint research Centre and the NEXUS Dialogues managed by DG INTPA combine an integrated multi-sectoral approach to water management at the river basin level with proactive and all-inclusive cooperative dialogues in relevant transboundary water basins in Africa.

[1] The High Level Panel on Water (HLPW) was co-convened in 2016 by the UN Secretary General and the World Bank President. It aims to identify suitable options to work towards SDG 6 (ensuring availability and sustainable management of water and sanitation for all).

Introduction

The African Union Agenda 2063 *"The Africa We Want"*, envisions a prosperous Africa, based on inclusive growth and sustainable development. To work towards these objectives, water, energy and food security must be ensured through the development and operationalisation of delivery mechanisms at the required scale. However, challenges arise due to Africa's high vulnerability to climate variability, water availability and commodity prices, which could be exacerbated in the future by climate change and a rapidly growing population. The complexity of these challenges across sectors and scales prevents the use of single sector policy perspectives and promotes the adoption of comprehensive frameworks which consider their multiple interlinkages.

***Figure 1**. Water, Energy, Food and Ecosystems play a vital part in Africa's development and could not be contemplated from a single perspective[2].*

In this regard, the Water, Energy, Food and Ecosystems (WEFE) Nexus approach is able to integrate management and governance across the multiple sectors involved, recognizing their interdependencies and the value of natural capital, ensuring coordination among stakeholders and identifying suitable policy solutions in order to optimize trade-offs and

[2] Photo credits: Michele Pellegrini; Cesar Carmona Moreno; Joanna Fatch and; Michael Schofield on Unsplash.

Joint Research Centre

maximize synergies across sectors. The key principles of the WEFE Nexus could be summarized as follows:[3].

- **Explore the spatial and temporal relationships between the different resources of a system** and consider the whole system's efficiency instead of the productivity of each component.
- **Understand the interlinkages between water, energy, food and ecosystems**, through the promotion of rational and inclusive dialogue in a decision-making framework and a conscious environmental approach to the efficient use of the natural resources.
- **Promote trade-off optimisation and take advantage of synergies across sectors**, by means of integrated policy solutions and cooperation.
- **Ensure coordination across sectors and stakeholders** to benefit from their interdependences and synergies.
- **Appreciate the natural capital of land, water, energy sources and ecosystems** and encourage governments and stakeholders to work towards a sustainable development.

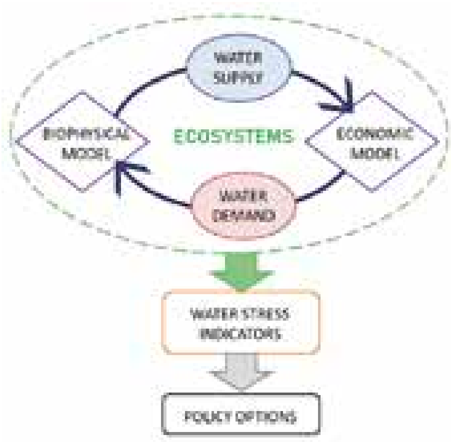

Figure 2. *WEFE integrated modelling methodology.*

Currently, the European Union (EU) is actively cooperating with the African Union (AU) in several policy initiatives framing the demand for the WEFE nexus approach to water development in Africa. In this context, the Water, Energy, Food and Ecosystems in Africa (WEFE-Africa) work programme of the JRC implements initiatives in collaboration with the directorates of International Partnerships (DG INTPA) and Environment (DG ENV) on WEFE Nexus assessment in relevant river basins in Africa. The integrated multi-sectoral approach to water management at the river basin level is combined with proactive and all-inclusive cooperative dialogues. The dialogues draw participation from the policy organs and decision makers of such African institutional partners as River Basin Organisations (RBOs); Regional Economic Communities (RECs); and research and academic institutions – including the AU-NEPAD[4] Water Centres of Excellence.

WEFE Nexus in practice

Although the WEFE Nexus cannot be regarded in truth as a completely new concept, it constitutes the latest development paradigm within the resources management field and benefits from the necessary momentum and political will for action to be put into practice. Governing the WEFE Nexus, indeed, could be considered as one of the key challenges of the present century, as it plays a significant role in the problem but it is also a part of the solution[5]. Reasons for the adoption of this framework include: its suitability to ensure the global security of resources, the ability to consider trade-offs between sectors, its multi-centric nature or its adequacy to integrate the Sustainable Development Goals (SDGs). However, the framework is also criticised for its current lack of operationalisation ("nexus thinking" rather than "nexus doing")[6].

Among the identified shortcomings of the approach, it is possible to highlight: 1) inability to provide a quantitative description of the real interdependences beyond the conceptual, qualitative understanding (mainly due to data and knowledge gaps) particularly relevant in developing countries; 2) lack of relevant indicators, systematic tools and monitoring data across scales to properly address the involved trade-offs; 3) inadequate integration of social components, such as power, politics or justice aspects (e.g scarce attention directed towards the poorest community members in the context of WEFE assessments or the overlooking of gender aspects); 4) misalignment of nexus boundaries with traditional administrative boundaries or management units; 5) complexity of unifying the accounting procedures across the WEFE components and capturing non-monetary values involved in synergies and trade-offs[6,7].

In this regard, the complexity of the WEFE context requires tailored solutions on a case-by-case basis around a set of concrete priorities, identified and agreed upon by policy makers to ensure its successful implementation, rather than a single conception of the nexus framework. The design of these solutions aims to overcome the problems of poor sectoral coordination and institutional fragmentation; to ensure the inclusion of directly involved stakeholders through appropriate identification of social aspects; to develop multi-model approaches with appropriate data exchange between the technical and political sectors; and, to ensure data production and availability through better coordination between key

[3] Position Paper on Water, Energy, Food, and Ecosystem (WEFE) Nexus and Sustainable development Goals (SDGs). 2019. Editors: C. Carmona-Moreno, C. Dondeynaz, M. Biedler, EUR 29509 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-79-98276-7, doi:10.2760/5295, JRC114177

[4] African Union - New Partnership for Africa's Development

[5] Allouche, J., Middleton, C., Gyawali, D. 2019.: The Water-Energy-Food Nexus: Power, Politics, and Justice. Abingdon, Oxon: Routledge

[6] Simpson, G.B., Jewitt, G. PW. 2019. The water-energy-food nexus in the anthropocene: moving from 'nexus thinking' to 'nexus action', Current Opinion in Environmental Sustainability, Volume 40, Pages 117-123, ISSN 1877-3435

[7] Liu, J., Yang, H., Cudennec, C., Gain, A.K., et al. 2017. Challenges in operationalizing the water–energy–foodnexus, Hydrological Sciences Journal, 62:11, 1714-1720, DOI: 10.1080/02626667.2017.1353695

actors sharing knowledge around common challenges (researchers, policy makers, resources managers and stakeholders).

Agriculture & Energy priorities

The African agri-energy sector currently offers great opportunities for development, as only 15-30% of the continent's hydropower potential is tapped[8], and the huge irrigation potential in its 63 shared river basins is not optimally leveraged to ensure food security. However, water insecurity is an undeniably limiting factor, exacerbated by complex hydrology, climate change and growing demands. Therefore, the following key development priorities have been identified for the African water sector, within the context of the express plans for productive use of water in the sectors of energy and agriculture[9]:

1. **Promoting a new narrative on water** that recognises the full potential of water in the African economy. The new narrative should foster an appreciation of the vitality of water in economic growth; job creation; and industrialisation.
2. **Strengthening the business case for water investments**, as well as raising the profile of water in national and regional development in Africa. In a context of high vulnerability to climate change/variability, the lack of investments to enhance human and institutional capacities, build infrastructure and improve information systems to support water management exacerbates the difficulties.
3. **Water infrastructure development** should be advocated for and promoted as a means to provide a service – which is water – to the economy in order to enable growth and development to happen. This should be extended to the opportunities for employment and wealth creation: not to mention peace, social security and political stability.
4. **Application of the High Level Panel on Water (HLPW) principles for valuing water** could benefit the strategies aimed at improving the investment outlook for water and related resources development. The principles provide a guideline for determining the real value of proposed investments; the associated costs; and the benefits that can be expected. In essence, they serve the purpose of improving the appreciation of the economics of water in a country, river basin or region.
5. **Investment led transboundary management and governance of water and environmental resources.** The aim is to consolidate and capitalise on the achievements to-date of implementing the principles of Integrated Water Resources Management. To this end, the African Water Resources Management Priority Action Programme 2016–2025 (WRM-PAP); the AMCOW Strategy 2018–2030; and the Africa Water Investment Programme (AIP) promote the following strategic initiatives: 1) establishing economic accounting for water to improve the financing and investment outlook for water resources management; 2) enhancing national-level capacities for collecting complete and reliable hydrometeorological and piezometrical data; 3) applying nexus perspective solutions to assure water, food and energy security; 4) improving agricultural water management; 5) implementing the Programme for Infrastructure Development in Africa (PIDA) transboundary water and energy projects and; 6) enhancing the use of wastewater and sludge for nutrient recovery in agriculture and bio-gas energy production.

***Figure 3**. Water security is a key aspect for Africa's development*[10]

Key WEFE challenges in Africa

Water: water management in Africa is particularly challenging, as 90% of water resources are found in 63 transboundary river basins and their per capita distribution is highly unequal and variable. Resource availability is highly conditioned by the continent's uneven precipitation patterns (both over space and time) and mean annual precipitation is particularly scarce in certain regions. Besides, vast areas of the continent are expected to undergo a further decline in precipitation trends in the coming decades, along with an increase of dry spells, heatwaves and drought conditions due to climate variability and change[11]. Impacts related to sea level rise (e.g. seawater intrusion into surface waters and coastal aquifers) could undermine water availability in coastal areas, and water pollution issues could further endanger the continent's water resources.

In this context, water scarcity could be exacerbated in places where it already exists or arise in areas traditionally exempted from it, as a combination of reduced available resources and soaring water demands. Water demands in Africa are expected to sky rocket in the next decades, due to the concurrence of multiple drivers (population and economic

[8] AMCOW. 2016. Africa Water Sector and Sanitation Monitoring and Reporting. Abuja, Nigeria: African Ministers' Council on Water

[9] Mbaziira, R 2020. Report on Development Priorities of the Water Sector in Africa placed in the context of Agri-Energy sectors: Draft Report. A report prepared for the European Commission's Joint Research Centre (EC-JRC). JRC123100.

[10] Photo credits: Michele Pellegrini. Sudan.

[11] Dosio, A., Jones, R.G., Jack, C., Lennard, C., Nikulin, G., Hewitson, B., 2019. What can we know about future precipitation in Africa? Robustness, significance and added value of projections from a large ensemble of regional climate models. Clim. Dyn. 53, 5833–5858. doi:10.1007/s00382-019-04900-3

growth, increase of energy demands or the development of irrigated agriculture). Regarding population growth, African population is expected to rise from 1.27 to 2 billion people up to 2050[12] and it will be accompanied by a sharp urbanization rate[13] (tripling the share of urban population by 2050[14]). Population and economic growth, in turn, will soar the continent's energy demands, which cannot be fully decoupled from water demands (electricity and water demands are expected to increase by 700% and 500% in the period 2012-2050, respectively[15]). Although industrial and domestic water demands will increase at a faster pace than the agricultural one, the latter will remain the largest[16].

Energy: since hydropower is the prevalent renewable energy source in most African countries, energy supply disruptions triggered by droughts affect negatively the energy mix, operational costs, CO_2 emissions and water consumption for energy generation. Besides, although hydropower still has a high growth potential in the continent, future developments should be carefully considered in water scarce areas, because water losses in reservoirs made it very water-intensive. In this regard, the substitution of fossil fuels by non-hydro renewable energies (wind, solar, bioenergy, geothermal) and the development of highly interconnected grids could reduce water use while contributing to fulfill Africa's rising energy needs.[17].

Food security: agriculture still constitutes the main economic activity in multiple African countries, employing more than a half of the continent's labor force. As it is primarily rainfed, it is highly vulnerable to climate variability, climate change and extreme events. Therefore, water related risks (and not the lack of arable land) are expected to be the largest contributors to food insecurity[18]. In this context, the necessary increase of agricultural productivity should be coupled with the improvement of its resilience and sustainability, supporting smallholders and promoting the adoption of local traditional practices to prevent soil degradation issues

Ecosystems: challenges include the degradation of water-related ecosystems due to infrastructure development, growing withdrawals, land use changes and pollution issues (e.g. presence of heavy metals, nutrients and pesticides, plastics or fecal bacteria and parasites).

Recommendations

As the projected soaring of competing demands over an increasingly scarce resource could have a high potential for conflict, it will be necessary to ensure a proper governance and cooperation at various institutional levels In this context, the Science-Policy interface (understood as the role of science as a driver of capacity, knowledge and information development to improve the effectiveness of policies) could be an essential instrument to promote cooperation and collaboration among the multiple stakeholders involved[19]. The use of participatory approaches such as WEFE NEXUS dialogues around concrete priorities and challenges could strengthen the acceptance of the strategies adopted. They could also benefit from a common vision of issues and information sharing practices between riparian countries and as an effective means to support water and science diplomacy[20].

However, the aspiration of an effective water governance, able to face up the identified WEFE challenges, could not be fulfilled if the detected human capacity gaps in the African water sector are not properly addressed. In this regard, the implementation of strategic decisions in the education and training sectors, along with the recognition of the central role of the water sector in Africa's development, could reduce the continent's dependence on external expertise and prevent the leakage of young talents to other sectors or lead directly to emigration.

Finally, the effective validation of scientific studies in Africa is still largely hampered by the low quality of data and data management. Overcoming data scarcity, as well as other obstacles related to the poor development of digitalisation on the continent (e.g. lack of expertise, lack of adequate financial resources to develop and maintain models or lack of adequate Internet connectivity) should also be a priority for achieving sustainable management of natural resources in Africa.[21]

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12 Neuville, A., Belward, A., Alguadis, M., Bertzky, B., Brink, A., Buscaglia, D., De Groeve, T., Kayitakire, F., Mulhern, G. et al. ., 2017. Science for the AU-EU Partnership: building knowledge for sustainable development. Publications Office of the European Union, Luxembourg. JRC107753. doi:10.2760/429935

13 Baranzelli, C., Jacobs-Crisioni, C., Maistrali, A., Kucas, A., Kavalov, B., Perpiña Castillo, C., Kompil, M., Lavalle, C. 2021. Urban development and regional connectivity in Africa. In "The African Networks of Centres of Excellence on Water Sciences Phase II (ACE WATER 2) WEFE Nexus assessment in Africa). JRC124127.

14 Hajjar, B. 2020. The children's continent: keeping up with Africa's growth. World Economic Forum Annual Meeting. Retrieved from: https://www.weforum.org/agenda/2020/01/the-children-s-continent. Last access: 12 February 2021.

15 World Bank's Thirsty Energy Initiative: http://www.worldbank.org/en/topic/water/brief/water-energy-nexus.

16 World Water Assessment Programme (Nations Unies), The United Nations World Water Development Report 2018 (United Nations Educational, Scientific and Cultural Organization, New York, United States) www.unwater.org/publications/world-water-development-report-2018/.

17 Hidalgo-Gonzalez et al. 2021.The Water and Energy Nexus in Africa. Science behind the debate, European Commission - JRC124435.

18 Du Toit, D. C. 2011. Food Security by Directorate Economic Services, Production Economies Unit. Gen reports. Retrieved November 18, 2012

19 Kanangire, C. et al. 2021. Water Science to support Policy Making in Africa. Science for Policy Briefs, European Commission - JRC124470.

20 Farinosi et al. 2021. Water-Energy-Food Security-Ecosystems in Africa. Technical Report, European Commission - JRC124433.

21 Rosetto et al. 2021. Framing the state-of-the-art in digital tools use for sustainable groundwater resource management in Africa. Science behind the debate, European Commission - JRC124455.

European Commission

SCIENCE BEHIND THE DEBATE

Human Capacity Development in the Water Sector in Africa

Key points

✓ The demand for Human Capacity Development (HCD) in the water sector is defined by the role that water plays in Africa's ambitions for socio-economic development. In this regard, the African Union Agenda 2063 *("The Africa We Want")*[1] identifies water security as a key priority area, whereas the Africa Water Vision 2025 highlights the necessity to improve water wisdom (the recognition of the unique value of water, leading to sustainable, equitable and efficient water management) in order to overcome capacity constraints in the water sector.

✓ Consequently, the development of the requisite human capital to sustain the vision of an integrated, prosperous and peaceful Africa requires the implementation of strategic decisions in the education and training sectors. Concretely, four broad categories of priorities were identified regarding HCD in the water sector: 1) building critical missing skills (particularly linked to sustainable development, utilisation and management of water and related resources) to enhance economic growth and social transformation; 2) updating and transforming the High Education (HE) and the Technical and Vocational Education and Training (TVET) sectors to integrate flexibility and adaptability for current and continuous learning in the education and training supply of human resources; 3) supporting Earth observation science and research, teaching and outreach and; 4) recognition of competences from non-formal and informal education and training[2].

✓ The JRC, in collaboration with the UNESCO-IHP, supported and coordinated the implementation of the African Network of Centres of Excellence on Water Sciences (ACEWATER) project. Its second phase (ACEWATER II) aims at fostering sustainable capacity development in the water sector at the scientific, technical and institutional levels. The project supports the AU-NEPAD[13] Centres of Excellence (CoEs), which are coordinated regionally by the University of Khartoum (Central and East Africa), l'Université Cheikh-Anta-Diop (Western Africa) and the University of Stellenbosch (Southern Africa), with a two-fold objective: 1) facilitate high-end scientific research on water and related sectors, in order to provide effective scientific and educational support to governments and; 2) implement HCD activities at regional and local level.

Introduction

To the extent that every sector of the economy is influenced by water, the realisation of sustained economic growth and social transformation is dependent on ensuring water security. According to the UN, water security entails *"to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability"*[4]

To address the African Union Agenda 2063 *("The Africa We Want")* strategic framework, the challenges are many: the observed trends in Africa's population (77% is currently under the age of 35 and 2 in every 5 children in the world will be born in the continent by 2050); urbanisation (urban population is expected to almost triple by 2050)[5] and lifestyle changes have implications for water demands, whereas the anticipated impacts of climate variability and climate change will shape the form, intensity and timing of water demands affecting water availability; and increase the risk and frequency of water-related hazards. To confront these challenges, a high level of technical ingenuity and capacity is required to develop the necessary water infrastructure for releasing Africa's development potential. A similar level of social ingenuity is also required to adjust policies, management and behaviours to address these increasing demands in the face of water scarcity and the adverse impacts of climate change. Therefore, talent and knowledge are both essential to achieve an effective water governance, with well-managed institutions deploying state-of-the-art solutions, integrated with the latest advances in ICT technologies.

[1] AUC. 2014. Agenda 2063: The Africa We Want.Addis Ababa: African Union Commission.

[2] Mbaziira, R 2020. Report on the Human Capacity Development priorities in the Water Sector in Africa: Draft Report. A report prepared for the European Commission's Joint Research Centre (EC-JRC). JRC123098.

[3]African Union - New Partnership for Africa's Development

[4] UN. 2013. What is Water Security? Infographic. Retrieved July 20, 2018, from UN Water Publications: http://www.unwater.org/publications/water-security-infographic/

[5] Hajjar, B. 2020. The children's continent: keeping up with Africa's growth. World Economic Forum Annual Meeting. Retrieved from: https://www.weforum.org/agenda/2020/01/the-children-s-continent/. Last access: 12 February 2021.

Hence, water education has been recognised as a key element in the Fourth Industrial Revolution (which is driven by the impact of emerging technologies on all aspects of human life) and the UN Water Global Framework and, more concretely, of the SDG-6 Global Accelerator Framework. However, the current state of the play regarding human capacity in Africa is a major cause of concern: according to the African Development Bank (AfDB), the continent has only 35 scientists and engineers per million inhabitants, compared with 2,457 for Europe and 4,103 for the United States[6]. Africa is struggling to boost its progress in science, technology and innovation due to lack of skills in these areas, as African students generally show preference for social and economic-related studies. Further limitation of low investment in research and development hampers the global competitiveness and productivity of the continent.

***Figure 1**. Building critical skills constitutes a priority for the African water sector. Photo by Fredy Alexander Pena Reyes.*

The existence of capacity constraints in the African water sector will endanger the achievement of the current development agenda, with the continent still highly dependent on developed countries aid and expertise, both in terms of knowledge and human resources (technical assistance/consultants). In this regard, the Africa Water Vision 2025 highlights the necessity of improving water wisdom to attain the aspiration of a prosperous Africa, based on inclusive growth and sustainable development[7]. Therefore, the ongoing strategic reforms in the education and training sectors provide the framework to identify and integrate the main HCD priorities in the water sector, which could be divided into four broad categories[1]:

1. **Building critical skills**: particularly, in the fields of sustainable development and the utilisation and management of water and related resources. The main objective is to enhance economic growth and social transformation, through the encouragement of technological enpowerment, e-education and adaptive learning.

2. **Fostering transformation in the High Education (HE) and Technical and Vocational Education and Training (TVET) sector**: in order to integrate flexibility, adaptability and continuous learning in the education and training supply. In particular, TVET is regarded as the most relevant training level where the biggest HCD gapsmust be addressed.

3. **Supporting Earth observation science and research, teaching and outreach**: there are numerous underdeveloped opportunities for the application of space science and technology to effectively manage resources such as water, land, forests, and marine ecosystems. The use of space technology is also of vital importance in generating sorely needed information to support decision making for the sustainable utilisation of the resources.

4. **Recognition of competences from non-formal and informal education and training (NFET)**: this overarching goal is twofold: firstly, enable tapping into existing technological preferences, cultural practices, local values and traditions of community learning to impart life skills for a wider contribution to management and running of a water sector and secondly, contribute to integrating mainstreaming indigenous water and pollution management knowledge and practices into lifelong learning (LLL) systems as well as into the education and training sector.

Overall, HCD programmes have to add value; therefore they must reflect national realities and be informed by appropriate and regular reviews of institutional schemas, sectorial and national development aspirations. The implementation of this type of framework is expected to overcome the challenges already detected through previous experiences, such as: 1) lack of clarity in defining the focus for HCD programmes directed to junior and senior water professionals and technicians; 2) conducting HCD analysis that were not necessarily institutionally inclusive or sectorally demand-responsive (thus the outcomes were generally neither institutionalised nor sustained); 3) inadequate connectivity and collaboration between key government, private and public sector, education and training institutions; 4) HE and TVET programmes outdated and unable to properly tackle the skills required by the sector (resulting in a negative perception of the industry towards the new graduates) and; 4) absence or inadequacy of internship or mentorship initiatives for students, trainees or participants in LLL.

The ACE WATER project

Overview and main goals

Since 2018, the African Union institutions have undergone a major reform, recognising and prioritising the role of knowledge and ensuring that it receives enough attention in

[6] AfDB. 2012. Briefing Notes for AfDB's Long-Term Strategy. Briefing Note 1: Higher Education, Science and Technology.

[7] United Nations. Economic Commission for Africa; United Nations. Economic Commission for Africa; African Union Commission; African Development Bank. 2003. Africa water vision for 2025 : equitable and sustainable use of water for socioeconomic development. Addis Ababa :. © UNECA,.http://hdl.handle.net/10855/5488

terms of policy, investments and capacity. In this context, the African Ministers' Council on Water (AMCOW) highlights the necessity of developing national frameworks on HCD, addressing junior and senior professionals and technician level capacity challenges. Therefore, the NEPAD CoEs are seen as a strategic asset for the development of the water sector in Africa and AMCOW requested the European Commission (EC) to establish a new support project based on the identified priorities for capacity development. The EC is firmly committed to better water and sanitation, and will focus its assistance in areas of greatest need. Henceforth, the EC's Joint Research Centre (JRC), in collaboration with the UNESCO-IHP, supported and coordinated the implementation of the African Network of Centres of Excellence on Water Sciences (ACEWATER) project. Its second phase (ACEWATER II) aims at fostering sustainable capacity development in the water sector at the scientific, technical and institutional levels.

Currently, UNESCO is addressing HCD in the water sector through several actions, such as the UNESCO's Water Family, in order to enhance professional skills and ensure an informed policy making process when it comes to water management. Building on these synergies, UNESCO-IHP is in charge of the HCD component within the ACEWATER II project, which aims to identify the main human capacity gaps of the African water sector and tackle them in an appropriate ways.

In this context, it is necessary to align the identified HCD priorities with the ongoing implementation of the strategic and operational plans of the individual centres of excellence within the network. Therefore, among the main goals of the ACEWATER II project (and/or its successor intervention) are to build synergies and complementarities and, above all, strive to avoid duplication of efforts, while making optimal use of available resources to maximise results and impacts. In order to achieve these objectives, a key aspect is the monitoring and evaluation (M&E) of the project's contribution to AMCOW's HCD programme, in terms of relevance, efficiency and effectiveness.

Among the wide range of activities developed within the context of this project, it is necessary to highlight the celebration of regional consultative workshops, in order to understand the characteristics of the water sector, the HCD context and the potential linkages with other relevant initiatives at the regional level. Besides, national dialogues were conducted with stakeholders, with a twofold objective: on one hand, to assess and prioritise HCD needs and; on the other hand, to validate the outputs of the process and to inform its implementation. The delivery of pilot training courses was also a key part of the project and a difficult one to perform due to the COVID-19 pandemic: as many institutions had to swich to emergency online teaching. It was necessary to perform a risk mapping and e-readiness assessment, in order to realign the planned courses and implement them online or, where possible, in blended learning of online and controlled face-to-face training. Finally, M&E was carefully tackled through a specific developed tool, along with impact studies to assess the real significance of the project.

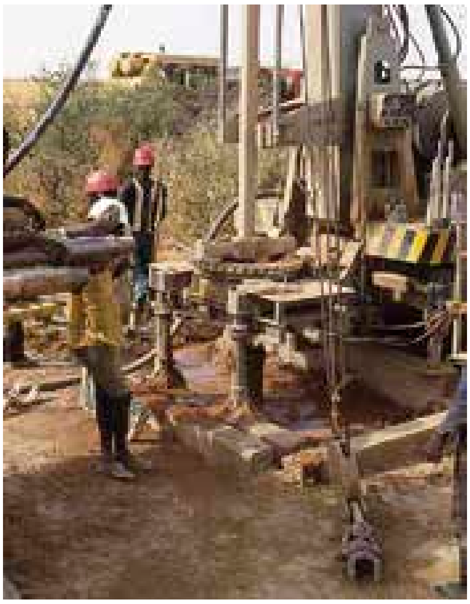

Figure 2. *African youth should be equipped with the necessary skills to face up the challenges of the continent's water sector. Photo by Michele Pellegrini.*

Lessons learned

One of the first lessons learned in this project is that the water sector stakeholders' analysis and capacity gaps assessments are time consuming, complicated and expensive to carry out and that therefore dedicated human and financial resources should be clearly directed to these tasks. This is especially essential as the vast majority of sector studies were highly regarded by all levels of institutional and sectoral participants and stakeholders.

Furthermore, it was noticed that institutions as part of a network are able to attract more funding than as single institutions leveraging funds coming from the EC. African institutions working in Science and Technology have limited capacity and resources, but they are among the very few source of local capacity and, as such, should be stimulated and further developed. This collective approach is the proposed solution to work towards a real sustainable capacity development. Among these institutions, the CoEs are particularly relevant and should be highlighted, given their profound knowledge of the local contexts, the long-term role they play in local knowledge management and the fact that they are institutionally and politically members of the African Union framework. The involvement of continental institutions, such as RECs and AMCOW, in the framework of the project, highly increased the impact of the CoEs, their role as sustainable players for capacity development and the institutional sustainability of this initiative.

In addition, the role and the visibility of the EC/JRC in the water sector in Africa has improved strongly thanks to the relationships established with the CoEs and their partner institutions in the water sector. In this regard, the EC/JRC played a fundamental role in facilitating the networking among the institutions of the different countries, including those not directly involved in the project.

Recommendations

With regard to the four categories of HCD priorities identified for the African water sector, the following recommendations can be made:

1. **Building critical skills**: it is imperative to grow and strengthen the AU-NEPAD African Network of Centres of Excellence in Water Sciences and Technology (CoEs) into a fully functional, Africa-wide knowledge and excellence network, fostering opportunities for development and water knowledge sharing across all the African Union Member States. The CoEs should, in turn, promote innovation to tackle the challenges of the low productivity and the mismatch between labour market requirements and skills. Therefore, they should equip the African youth with the flexible skills needed for tomorrow's job market, through facilitating the development of new professional profiles such as digital water management specialists or green/smart water use technologists. Besides, as the COVID-19 pandemic has been a turning point to bring to light the potential of e-learning, digitalisation and moving to online platforms, as key issues to foster the exchange of skills, knowledge and ideas.

   Finally, it is crucial that the private sector also brings its knowledge, both in terms of technology and management. In this regard, the EC (through DG INTPA) is supporting the Global Water Operator Partnership, which aims to further promote HCD through business to business cooperation and collaboration between water operators from the EU and Southern countries.

2. **Fostering transformation in the HE and TVET sectors**: in order to improve the relevance of the sector and upscale its capacity, along with the employability and the distribution of the workforce, the sectors should be suited to impart skills in all areas of training and learning; be they formal, informal or non-formal. For the water and sanitation sector, it is imperative to: 1) develop and institute officially recognised and accredited trainings for the water and wastewater sectors; 2) raise the level of prestige and attractiveness of sanitation related occupations and eliminate the gender inequalities; 3) based on the sector studies, review and update the curricula, in order to facilitate the development of needed skills from the basic to the higher education level. The impact of COVID-19 has also pointed out the added value of online learning and the structural gaps in both sectors (and especially in the TVET one), on the application of this additional learning tool.

3. **Supporting Earth observation science and research, teaching and outreach**: many of the space-derived services and products currently used in Africa are imported. Therefore, to actualise the vision of the Agenda 2063, the development of indigenous capacity to operate and maintain core space capabilities cannot be overemphasised. In this regard, the NEPAD-CoEs, through the HCD Programme, should champion: 1) the development of skills and expertise in Earth observation and remote sensing applications and their use; 2) the development of Earth observation services and products; 3) the development of specialised curricula, materials and teaching aids to introduce space science and astronomy; 4) awareness raising among the public, users and policy and decision makers and; 5) knowledge sharing among African experts, users and stakeholders.

   Currently, the JRC is working towards the implementation of a Knowledge Centre, which would be able to deepen the uptake of Earth observation for different policy areas. Environmental monitoring in Africa is already supported by the so called E-stations (organised through the project Global Monitoring for Environment and Security (GMES) & Africa), which allow different regional observatories to monitor and forecast their environmental situation and identify hotspots. Efforts are now directed to integrate coastal climate capabilities in the E-stations, in order to have even better forecast possibility for the local stakeholders.

4. **Recognition of competences from non-formal and informal education and training (NFET)**: there is an urgent need to mainstream indigenous water and pollution management knowledge into lifelong learning systems, HE and TVET institutions through: 1) the adoption of a competence-based approach to curriculum reform within a lifelong learning framework; 2) improving the understanding of, and responding to the demands for individual, community and societal core skills and competences; 3) creating more opportunities for adult education and community learning (including NFET schools) and; 4) tapping into existing technological preferences, cultural practices, local values and traditions of community learning and imparting of life skills.

Finally, the way forward should address several issues, such as: 1) strengthening the relationship with key partners from Northern Africa to expand the current network to this region; 2) upscaling the pilot training courses to reach a critical mass of water professionals; 3) boosting mobility and the exchange of skills, knowledge and new ideas; 4) use national HCD frameworks to leverage additional resources, both internally (through the national budget and the private sector) and through external funding.

Full references in:

Mbaziira, R 2020. Report on the Human Capacity Development priorities in the Water Sector in Africa: Draft Report. A report prepared for the European Commission's Joint Research Centre (EC-JRC). JRC123098

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SCIENCE BEHIND THE DEBATE

The Water and Energy Nexus in Africa

Key points

✓ The nexus refers to the complex interactions between water and the energy industry. Water is needed for electricity production, fossil-fuel extraction, transport and processing, or irrigation of energy crops. On the other hand, energy is needed for extraction, treatment, and distribution of drinking water, wastewater treatment and desalination.

✓ Electricity and water demands are expected to grow significantly in Africa, by 700% and 500%, in the period 2012-2050[1]. The African energy systems are small sized, poorly electrified, reliant on oil for power generation, and poorly interconnected[2]. Hydropower is the dominant renewable energy source in Africa.

✓ The availability and temperature of water resources determines the operation of power plants, which need water for cooling and for hydropower generation. Thus, climate variability has a strong impact on the energy mix, operational costs, CO_2 emissions and water consumption for energy generation[2].

✓ Africa has a large untapped hydropower potential. New developments should be carefully assessed in regions where water scarcity is already an issue. Hydropower is very water-intensive due to the evaporation losses in reservoirs. The substitution of fossil fuels by non-hydro renewable energies (such as wind or solar) reduce significantly water use while helping to meet the increasing energy needs of the continent[3].

Introduction

The water-energy nexus is particularly challenging in Africa. The combined effect of economic and demographic growth is expected to soar electricity needs[1] up to 700% in 2050 (when compared to 2012). Energy and water demands cannot be fully decoupled. The growing energy demand will add pressure on water resources in certain areas (which are already characterized by water scarcity), competing directly with other sectors (e.g. agriculture, urban supply) and triggering potential conflicts among water users.

Water availability and water temperature have an effect on cooling systems which can constrain power plants' operation. Currently, hydropower is the dominant renewable energy source in most African energy systems, supplying up to 51% of electricity in Sub-Saharan Africa in 2018 (excluding South Africa)[4]. In this context, energy supply disruptions due to droughts frequently lead to negative economic and health aftermaths in African countries, affecting the energy mix, operational costs, CO_2 emissions and water consumption for energy generation.

African energy issues have received increased attention on the European policy agenda and this focus has been further elevated with the recent communications on the European Green Deal[5], which stresses that *"climate and environmental issues should be key strands in relations between the two continents"*, and the communication on a comprehensive strategy with Africa[6]. Among the ongoing initiatives, the Water-Energy-Food-Ecosystems (WEFE) project of the Joint Research Centre (JRC) aims to support the design and implementation of cross-sectoral policies, to improve the resilience of water-using sectors and the preservation and sustainability of freshwater resources. Concretely, the analysis of the water-power nexus in Africa has been addressed within the context of the WEFE project, through the development of a specific modelling framework able to quantify the economic impacts, emissions, water withdrawals and consumption, and the detailed operation of the power system under current and future scenarios.

The African Power Pools

Currently, five power pools are established in Africa: West, Southern, North, Eastern and Central African Power Pool, respectively. Their main goal is to coordinate power system planning and operation across their members, which is reflected in growing interconnection levels and a gradual implementation of market-based integrated approaches. Future interconnections between power pools are also planned.

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[6] EC. 2020. Towards a comprehensive strategy with Africa. JOIN (2020) 4 final

West African Power Pool[7]

The West African Power Pool (WAPP) is characterized by its high vulnerability to climate change, and it is already experiencing impacts on its food, water and energy security which could be further challenged by a rise of the demand associated to economic and population growth. Although the region is rich in water resources (approximately 27% of Africa's internal renewable water resources), it suffers from chronic water deficits due to the uneven distribution of rainfall and flows in time and space, insufficient knowledge about water resources, low exploitation of potential resources, and poor resource management. Energy resources are also plentiful but unenvenly distributed, and the renewable energy potential is underused. Electrification rates are low and there is a high dependence on biomass. The power generation mix has a significant share of gas and oil power plants and the interconnections between countries are very limited.

The operation of the WAPP's power system in the future will depend heavily on the availability of water resources, which is nevertheless outside the control of policy planning. This translates into a high volatility of the system cost, which can be partially mitigated by the addition of thermal capacities foreseen in the WAPP's master plan. However, that would lead to increased emissions and a higher electricity bill. Hence future policy scenarios should explore technology portfolios which could achieve low volatility, low cost and low emissions simultaneously.

Southern African Power Pool[8]

The Southern African Power Pool (SAPP) is the most advanced among the African power pools in terms of market development. Its member countries are quite heterogeneous as regards population size and economic development.

Power generation in the SAPP relies largely on coal and water from the Congo, Orange and Zambezi rivers and their tributaries. Both energy sources are water intensive, making regional electricity generation prone to water-related impacts that, in conjuntion with other factors, can cause extended periods of electricity supply interruptions with high economic costs (in Malawi, South Africa and Tanzania have been estimated at 5-7% of the GDP) which could be even worse in the future. In addition, the planned developments will increase the concentration of the SAPP's hydropower capacity in the Zambezi basin, from about 70% to 85% in 2030. This growing accumulation of hydropower in a single basin could escalate the future water-related risks in the SAPP[9].

The analysis of the water-power nexus in the SAPP shows that the discharge variability has caused electricity supply interruptions in recent years, mostly in those SAPP countries not yet interconnected, namely Angola, Tanzania and Malawi (where the levels of unserved energy could reach up to 25% of the yearly country demand). Results also point out that a higher availability of water can substantially alleviate the negative economic consequences of unserved electricity in the SAPP (both on electricity price levels and hampered economic activity).. Besides, it would be necessary to address the future impacts of climate change and the occurrence of extreme events (in South Africa, floods already reduced the operation of the coal fleet with impacts on several SAPP countries).

The expansion of interconnections could increase the resilience against electricity supply interruptions, significantly reducing and smoothing electricity prices and the unserved electricity levels. Better interconnection of the SAPP countries could reduce the system costs by 20%. Therefore, emphasis should be placed on grid expansion policies, as they are the only ones which can be directly controlled through policy decisions.

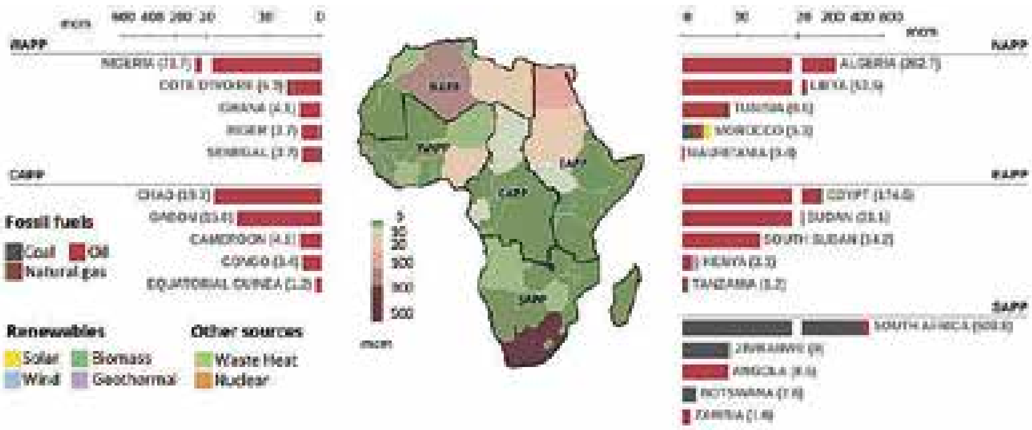

Figure 1. *Total water consumption (million cubic meters, mcm) per country by fuel type for the five power pools in 2016. Source: González Sánchez et al. (2020)*[17]

[7] De Felice, M., González Aparicio, I., Huld, T., Busch, S., Hidalgo González, I. 2019. Analysis of the waterpower nexus in the West African Power Pool - Water-Energy-Food-Ecosystems project, EUR 29617 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-98138-8, doi:10.2760/362802, JRC115157

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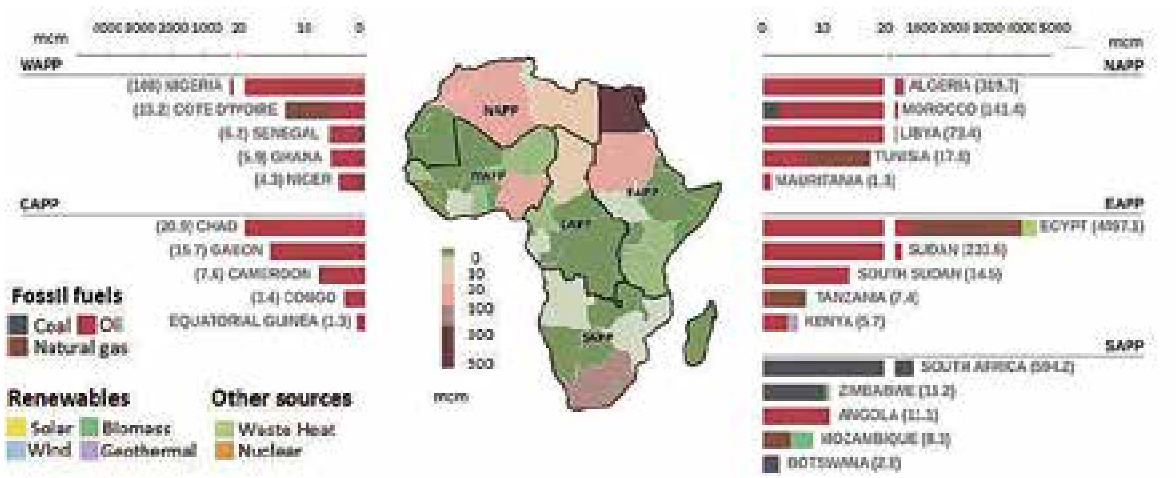

Figure 2. *Total water withdrawal per country by fuel type for the five power pools in 2016. Source: González Sánchez et al. (2020)*[17]

The North, Eastern and Central African Power Pools[10]

The renewable and fossil potentials vary significantly between the three remaining power pools. The North Africa Power Pool (NAPP) is mostly dominated by fossil fuels and has higher electrification rates, while the Central African Power Pool (CAPP) and the Eastern Africa Power Pool (EAPP) are dominated by hydropower and characterized by low electrification rates. In particular, EAPP is the most diverse one, as some of its members are entirely dependent on fossil fuels and others rely completely on renewable energies. In this context, an open modelling framework and input dataset have been developed for these three power pools, considering both the current (or near-future) situation and several long-term scenarios constrained by climate-related CO_2 limitations.

According to the results, in the reference scenario, capacity additions varying between 573-589 GW are anticipated by the year 2045, for an overall demand which is expected to grow by 16% by 2025, 89% by 2035 and 216% by 2045. Besides, a higher degree of interconnection could significantly reduce the load shedding and curtailment, especially in several countries with a very low generation capacity that do not share any cross-border lines with the neighbours (e.g. Central African Republic and South Sudan).

The analyses also highlighted the dependence of the power sector on the availability of freshwater resources in the three power pools. Thus, differences between dry and wet years could vary the share of electricity coming from hydro units up to 5.2%, introduce changes in the operational costs around 1.4 billion € (or 3.28 €/MWh) and induce oscillations in CO_2 emissions up to 15 millions tons per year. Besides, it is important to highlight that the water consumption of the power fleet in the NAPP is significantly low in relation to its water withdrawals (Figures 1 and 2). This is due to the large share of once-through cooling systems in NAPP, which increase the water temperature, but do not limit the quantity of water available for other users.

In this regard, a highly interconnected grid could reduce water withdrawals up to 50% across the three power pools (in comparison with the current system configuration) and water consumption between 50% in NAPP and 2% in EAPP. In addition, interconnections could reduce the price of electricity (between 2.7% in extremely wet seasons and 3.9% in extremely dry ones), as well as a higher integration of renewable sources. Furthermore, carbon emissions could be reduced by more than 32% (in comparison with the reference scenario).

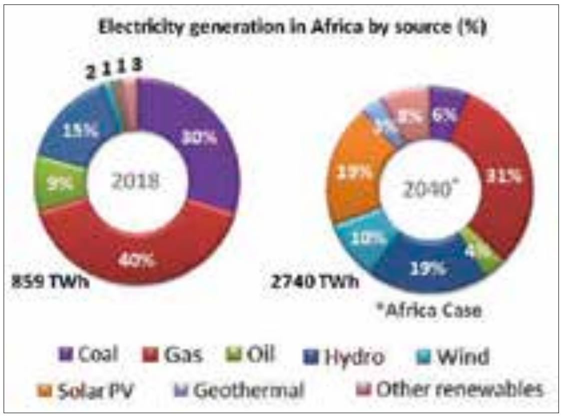

Figure 3. *Electricity generation in Africa by source (%) in 2018 and 2040 in the Africa Case scenario. Adapted from IEA (2019)*[4]

Current and future perspectives

Africa has the highest untapped hydropower potential in the world, as it is estimated that only 11% (37 GW) is currently used. Although in the last decade the hydropower installed capacity has increased at an average annual rate of 4.4%, the effects of climate change and the ageing of the hydropower facilities[11] have prevented a similar growth in hydropower generation. In any case, hydropower plays an important role (Figure 3) in all African regions except from North Africa,

[10] Pavičević, M. and Quoilin, S., Analysis of the water-power nexus in the North, Eastern and Central African Power Pools, De Felice, M., Busch, S. and Hidalgo Gonzalez, I., editor(s), EUR 30310 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-20874-7, doi:10.2760/12651, JRC121098.

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producing up to 17% of the total electricity in the continent, and expecting to grow in the following decades (generating more than 23% by 2040).[12]

However, the future energy mix will present significant differences at the regional level: while North, Eastern and Southern Africa could obtain renewable energy from windpower, concentrating solar power (CSP) will be important specifically in North Africa, solar photovoltaics (PV) in both the Northern and Southern regions and geothermal sources in East Africa[13]. With regard to the latter, geothermal energy is expected to double its share by 2040 (from 2% of electricity generation in Subsaharan countries (excluding South Africa) to 4%)[14]. Despite its marginal role at the continental level, this energy source could be highly relevant for some small African countries (e.g. Djibouti, Comores), as it might cover most of their electrical energy needs[15].

To sum up, the use of non hydro renewable energies could offer an interesting alternative to fossil fuels, in order to contribute to the reduction of water use while fulfilling the increasing energy demand of the continent. As power systems pose impacts on both water resources' quantity and quality, the role of hydropower as a water user cannot be disregarded. In Africa, water losses linked to hydropower generation accounted for 42 billion cubic meters in 2016 (Figure 4), whilst the correspondent to the combination of all the other fuel types was estimated at 1.2 billion cubic meters..[16] According to future projections,. evaporative losses in the African hydropower sector could undergo a significant increase in the next decades:: they could range between 93.1 and 94.8 billion cubic meters by 2030 and between 139 and 160.7 billion cubic meters by 2050 (depending on the global warming scenario, Figure 5).[17].

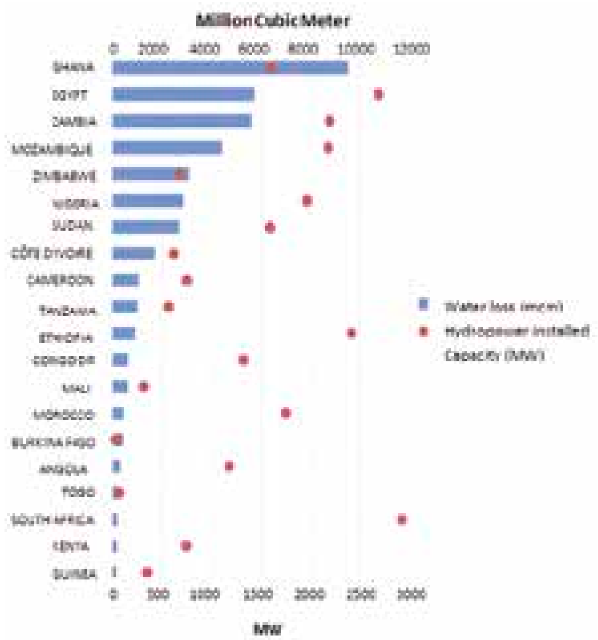

Figure 4. *Water loss from evaporation vs hydropower installed capacity for the top 20 countries with the highest water loss in the year 2016. Source: González Sánchez et al. (2020)*[17]

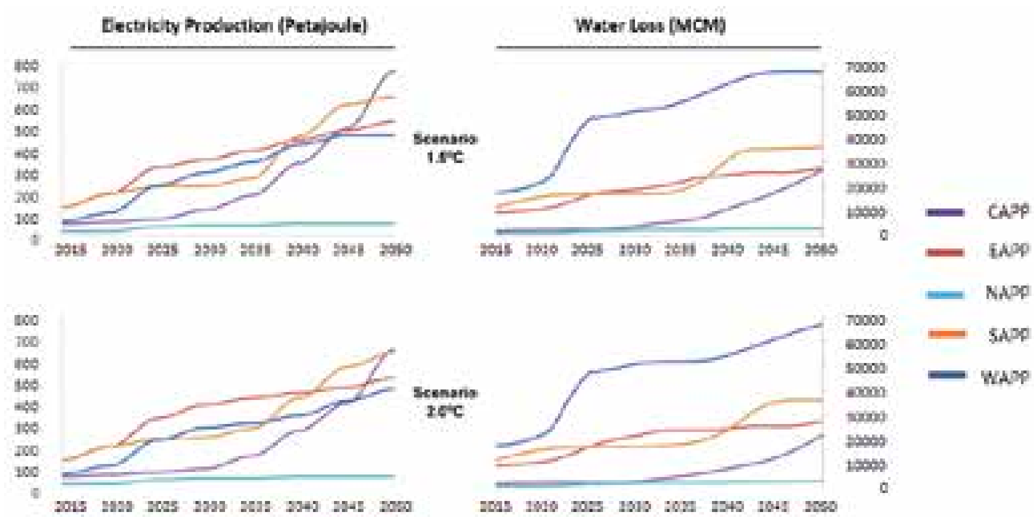

Figure 5. *Future projections of hydroelectricity production and water loss associated to hydropower. Source: González Sánchez et al. (2020)*[17]

[12]IEA. 2020. Climate impacts on African hydropower.

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European Commission

SCIENCE BEHIND THE DEBATE

Status of Geothermal industry in East African countries

Key points

- ✓ Geothermal energy is an indigenous energy source less prone to the instability of the international Oil and Gas (O&G) market, which requires limited operating and maintenance expenditures and could offer a constant generation output independent from weather conditions, a competitive levelized cost of electricity generation (LCOE) and low lifecycle greenhouse gas emissions. However, it is characterized by a long project execution cycle, where important initial investments are necessary and which involves remarkable mining risks (mainly related to the exploration stage).
- ✓ The East African Rift System (EARS) geodynamic context creates highly favourable conditions for the existence of geothermal systems at economically and technically drillable depths (less than 4,000 m), with a global potential estimated at about 20,000 MW (mainly located along its Eastern Branch, which extends from Eritrea to Tanzania and crosses Djibouti, Ethiopia and Kenya).
- ✓ At present, only Kenya has exploited a small part of its geothermal resources. Among the main reasons for the delay of geothermal development in East Africa are: the absence of clear and coherent legislative frameworks; the lack of local technical and managerial skills; remoteness of many geothermal areas in relation to O&G regions (where most of the drilling contractors and service providers are based); inadequate financing at the early stages of the projects; competition from other energy sources and; the issue of the remunerative price for the generated electric power in still poor developed national electric markets.
- ✓ International initiatives to help East African countries to overcome these issues include: capacity building to create the necessary legislative framework in each country; creation of public companies in charge of initial exploration activities; grants covering the variable costs of the phases characterized by the highest mining risks and; technical assistance and consultant support to national institutions and geothermal operators.

Introduction

The general objective is to frame the state-of-the-art of the geothermal resource development in East African countries with the focus on geothermal activities aimed at generating electric power by using either flashing or Organic Rankine Cycle (ORC) plants. Thus, direct uses of geothermal energy such as cooking, space heating and cooling, greenhouse heating, crop drying, aquaculture and heat for industrial processes are not addressed here.

Geothermal resources, consisting in the heat contained in the Earth crust, are presently exploited for both electric power generation and for direct uses. Favourable geodynamic environments allow founding exploitable geothermal systems at economic and technical feasible depths. Apart from the utilization of low temperature resources (<100°C), only made for direct uses, the generation of electric energy is made from medium (between 100°C and 200°C) and high (>200°) temperature geothermal systems. Almost all the high temperature geothermal systems exploited today are hydrothermal systems from which heat is extracted by means of wells producing fluids contained in a permeable reservoir. According to thermodynamic conditions, the reservoir can be either vapour or liquid dominated, depending on the fluid phase controlling the reservoir pressure distribution.

This type of renewable energy is characterized by: low environmental impact and greenhouse emissions when compared to energy generated using fossil fuels; quite constant generation output independent from weather conditions (which makes it particularly suitable for base load electric generation); high initial capital costs; low operating and management expeditures and; remarkable mining risks mainly related to the performance of the exploratory drilling phase.

Geothermal power also requires a long project execution cycle, which could be divided into eight key phases[1]: 1) Preliminary survey; 2) Exploration; 3) Test drilling; 4) Project review and planning; 5) Field development; 6) Power plant construction; 7) Commissioning and; 8) Operation. The three first phases (which could be broadly called the exploration stage) are seen as the riskiest part of the project development, because either confirm the existence of a geothermal reservoir suitable for power generation or not. It may take approximately seven years[2] (usually between 5 and 10 years) to develop a typical full-size geothermal project with a 50 MW turbine as the first field development step. Therefore, geothermal energy could not be regarded as a quick fix for any country's power supply problems, but it rather should be part of a long-term electricity generation strategy.

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East African Rift System (EARS)

East Africa is characterized by the presence of the East African Rift System (EARS) with: the Eastern branch extending from Eritrea to Tanzania and crossing Djibouti, Ethiopia and Kenya; and the Western branch extending from Uganda to Mozambique and crossing Burundi, Rwanda, Zambia, Tanzania and Malawi (Figure 1). While this geodynamic context creates highly favourable conditions for the existence of geothermal resources at economically and technically drillable depths, at present only Kenya has developed its geothermal resources with an installed electric power of 865 MW, representing about 30% of total installed power, against estimated resources amounting to some 7,000 MW.

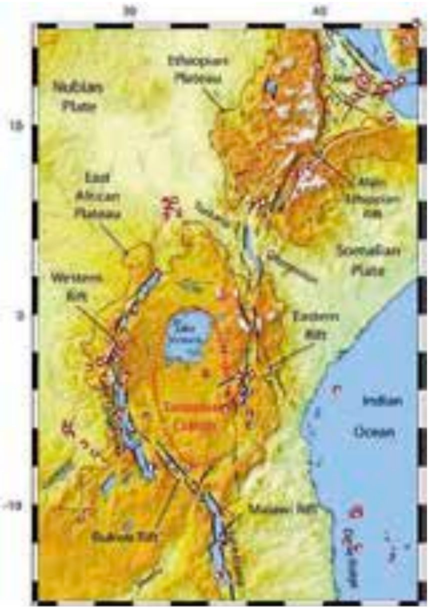

Figure 1. The East African Rift System[3]

Currently, it appears to be evident that the countries crossed by the Eastern Branch of EARS have a definitely higher geothermal potential than the ones located along the Western Branch, mainly concentrated in the Afar depression and the Ethiopian and Kenyan Rift Valleys. Even if not huge on an absolute scale, the resources inferred in Eritrea, Djibouti and the Comoros (the latter not actually pertaining to the Eastern Branch of EARS), if developed, would contribute to a large fraction of their present and future electric network base load. In the case of the countries crossed by the Western Branch, they have a lower geothermal potential, mostly related to medium, rarely high, temperature fault controlled geothermal systems, whose utilisation for electric power generation would require ORC power plants. As a consequence, about 95% of EARS estimated potential amounting to some 22,400 MW belongs to geothermal areas located along the Eastern Branch.

The role of geothermal energy in the energy mix of the East African countries depends on the present status of the energy market of each country, on the potential of indigenous energy sources, including geothermal energy, and strategic choices taken by each government. There are several reasons for the delay of geothermal resources development experienced so far by these countries, such as:

- Lack of clear and coherent legislative frameworks, regulating the activities of both public and private investors in several countries.
- Lack of local technical and managerial skills, able to conveniently support the exploration and exploitation of geothermal resources.
- The remoteness of many East Africa geothermal areas from developed O&G regions, where most of the drilling contractors and service providers are based, and then the absence of infrastructures and logistic facilities supporting the drilling activities characterising well developed O&G regions.
- Inadequate financing of the early stages of geothermal projects; commercial banks reluctance to participate in the exploration phase and the need for more risk reduction opportunities, which facilitate the investment by both public and private operators.
- Competition from other energy sources, such as hydropower in Ethiopia and several other countries, which creates a challenging environment for geothermal projects in the region.
- The issue of remunerative price for the generated electric power in still poor developed national electric markets.

Historically, reconnaissance and preliminary surface studies on geothermal prospects in East Africa where performed by public institutions or companies supported by international donors and consultants. Often, this approach has been characterized by a discontinuous performance of exploration phases separated by long periods of inactivity, sometimes accompanied by the switch of operations from one institution to another one, with loss of skilled personnel and know-how. More recently, most of the countries have developed regulatory environments in which both public and private operators, as well as private-public initiatives, are allowed to develop the geothermal resources.

The way forward

Regarding the forecasted role of geothermal energy in the generation of electricity in sub-Saharan countries, Figure 2 shows the electricity supply by type, source and scenario in sub-Saharan Africa, excluding South Africa[4]. The situation in 2018 is compared to two different scenarios (Stated Policies & Africa Case) foreseen for year 2040. The IEA's Stated Policies Scenario is based on current and announced policies, while the Africa Case scenario is a new scenario built by IEA around Africa's own vision for its future. It incorporates the policies needed to develop the continent's energy sector in a way that allows economies to grow strongly, sustainably and inclusively.

[3] Omenda, P.A. 2018. Update on the status of Geothermal Development in Africa. https://geothermal.org

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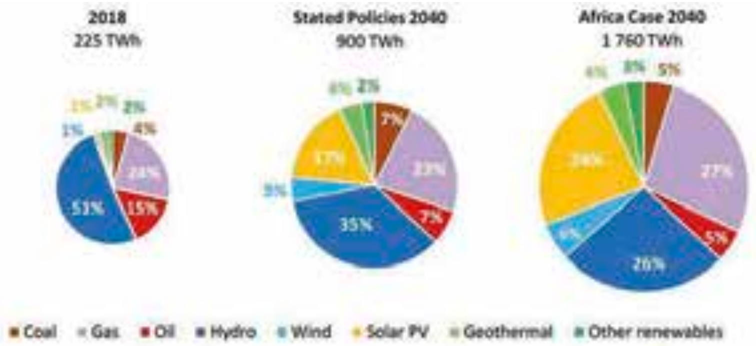

Figure 2. Electricity supply by type, source and scenario in sub-Saharan Africa (excluding South Africa), 2018 and 2040[4]

In 2018 geothermal power accounted for 2% of electricity generation and it is expected to represent in 2040 4% of electricity generation in both IEA's scenarios. Thus, geothermal is expected to double its contribution share in 2040, but still representing a small fraction of electricity generation, in particular if compared to the important increment of Solar PV, which will compensate for the reduction of hydropower contribution. These scenarios both suggest that, even if most of the investments on renewable energies will be drained by Solar PV, geothermal will anyway experience a large increment of generated energy and then of installed power.

In order to help East African countries to overcome the identified barriers to the development of geothermal resources utilization, international organizations and financial institutions are actively collaborating with national governments to create the necessary legislative framework in each country, to facilitate the capacity building with the creation of excellence centres and the organization of dedicated courses and conferences. On the other hand, financial and international institutions, such as WB, AU, EU, IRENA, NDF, AFD, AfDB, JICA, USAID, etc., are providing both grants and low interest loans to help public and private operators in the various steps of geothermal resource development, from the exploration surveys to the construction of power plants.

In addition, the following technical approaches, derived from experiences and lessons learned, are believed to reduce risks and improve the bankability of geothermal projects[5]:

- Sound exploration for high-quality geological data.
- Linking technical and commercial analyses to the

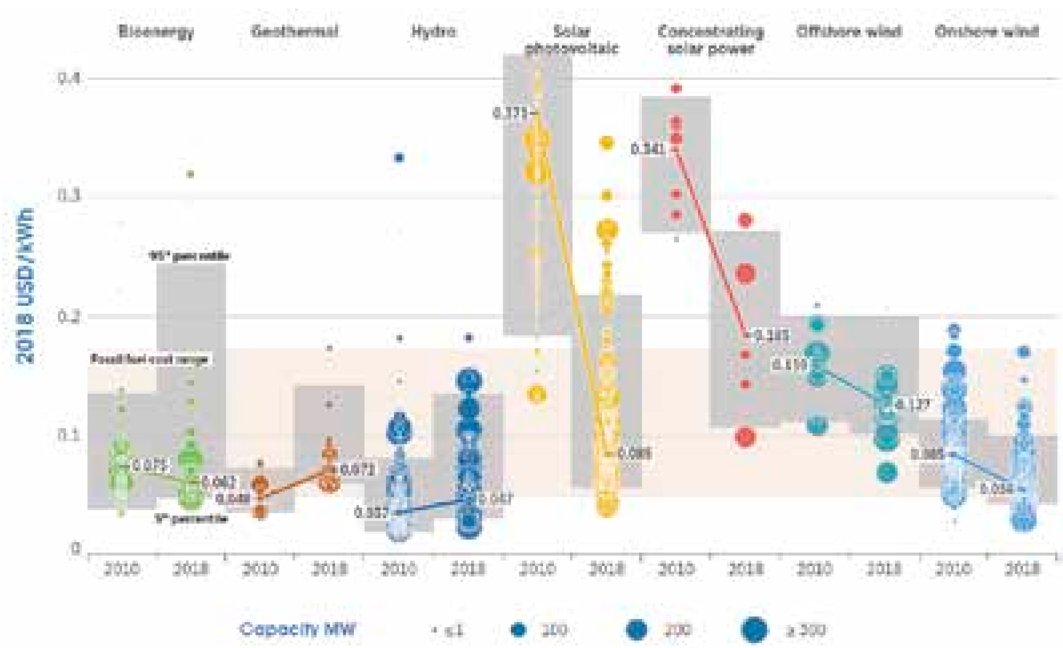

Figure 3. Global LCOE evolution of utility-scale renewable power generation technologies in the 2010–2018 period. Real weighted average cost of capital is 7.5% for OECD countries and China and 10% for the rest of the world[4]

[5] IRENA. 2018. Geothermal Finance and Risk Mitigation in East Africa. Key findings from a regional workshop held in Nairobi, Kenya, 31 Jan-2 Feb 2018

development of realistic prefeasibility studies prior to making major investments.

- Generating early revenue through wellhead generators: it appears that installing wellhead power plants is advantageous when an early electric generation can be obtained during a long-term field development in quite large fields, and when the wellhead power plants can be relocated on another field or field sector when the final power plant starts its operations.
- Supplement project revenues through direct use applications and sale of other by-products such as heat, lithium, CO_2, silica, etc.

In any case, geothermal energy shall be competitive in relation to other energy sources, either other renewables or fossil fuels. Most of the plants allows a LCOE lower than about 0.08 USD/kWh[6], which is competitive with electricity generated with fossil fuels (Figure 3). Cheaper renewable energy sources like Solar and Wind not affected by the mining risks of geothermal energy may likely be preferred by many international and national investors.

The countries that at present show the best geothermal perspectives, mainly located along the Eastern Branch of the EARS, are:

- **Eritrea**: a single explored site, with reported potential of 70-100 MW. Further activities aimed at completing the surface exploration and target exploratory drillings seem worth to be performed, as the installation of a 50 MW geothermal plant in Eritrea would already cover most of its present national base load.
- **Djibouti**: surface and drilling exploration dates back to late '70s, with several prospects recently explored within the Asal rift area at Gale le Koma and Fialé caldera. In Djibouti too the installation of a geothermal power plant of some 50 MW would cover most if its electric network base load, consistently reducing the use of imported oil.
- **Ethiopia**: the country has a large inferred potential in the order of 10,000 MW, but only a 7.5 MW power plant was installed at Aluto caldera, now not in operation. The situation has recently changed thanks to a new geothermal proclamation and regulations issued in 2016 and 2019, respectively. Geothermal development in Ethiopia will face the competition with cheaper renewables, such as the huge hydropower resources presently developed by Ethiopian Electric Power (EEP) and the large estimated solar and wind resources.
- **Kenya**: it is the leading country as far as the geothermal development in East Africa is concerned. Kenyan experience is taken as a successful example of geothermal industry, characterized by the development of the great Olkaria geothermal field by a public electric utility (KenGen), with both KenGen and GDC providing consultancies and services to neighbouring countries. Kenya has been also chosen as the location of the Africa geothermal Centre of Excellence operated by GDC in collaboration with KenGen.
- **Tanzania**:it has deployed several efforts in last years, both with the creation in 2011 of TGDC, the state-owned company with the main mission to develop the national geothermal sector, as well as with the exploration of the most promising prospects. The potential has been recently conservatively estimated in 500 MW. When compared to the planned electric power development in Tanzania, it is clear that geothermal energy will play a minor role in the future energy mix, unless additional exploration activities identify new promising prospects.
- **Comoros**: surface exploration of the Karthala prospect in Grande Mayotte allowed to identify a geothermal potential of up to 40 MW, largely exceeding the present and future base load of the country. Exploration wells have been targeted and a project is underway, aimed at drilling three exploration wells.

In conclusion, thanks to the efforts of both national governments and international stakeholders, the geothermal energy in the Eastern Branch countries of EARS seems to be at a turning point in particular in Ethiopia and Djibouti, with Kenya going on in an accelerated way along an already established successful path. Geothermal exploration in the Comoros has also good perspectives with geothermal potential to be confirmed, but largely exceeding the present base load of the country..

The geological settings and the exploration activities performed so far suggest that the countries crossed by the Western Branch of EARS have a lower geothermal potential, mostly related to medium, rarely high, temperature fault-controlled geothermal systems whose utilisation for electric power generation would require ORC power plants.

Experiences recently gained with the exploration of fault-controlled systems in the Western Branch and related new achieved understanding, have implications for both taylored geological exploration approaches and the identification and prioritization of prospects in the Western Branch countries, which will likely allow to identify new promising possibilities.

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Framing the state-of-the-art in digital tools use for sustainable groundwater resource management in Africa

Key points

- ✓ Groundwater is a resource of increasing prominence in Africa yet to be developed in full capacity.
- ✓ While it is clear that data gathering is of outmost importance for many African aquifer systems, Information and Communication Technologies (ICTs) may help toward more effective data management.
- ✓ For digital tools we intend all those tools used for data gathering, archiving and analysis, spanning from digital sensors, to Geographic Information Systems, numerical modelling up to advanced artificial intelligence for data-based groundwater resource planning and management.
- ✓ We performed a comprehensive literature review on the use of groundwater numerical models in the last twenty years in Africa and ran a survey targeting African groundwater experts, to obtain their insights about the present and future perspectives of the use of digital tools.
- ✓ Digital tools are recognised as needed tools for groundwater resource management at national and regional levels in the African countries .
- ✓ At present, most used digital tools are calculation spreadsheets, then GIS applications, followed by numerical modelling tools. The latter are still seen as research oriented tools. Their use in professional work is relevant, while emerging in public authorities.
- ✓ Commercial software solutions still dominate the market, while open source ones have just appeared. Open source and free software (largely preferred to commercial solutions) would be used if adequate training wasprovided. Capacity building on the use of digital tools for groundwater management is (extremely) necessary.
- ✓ Main barriers to digitalisation are: i) data scarcity, ii) inadequate financial resources to develop and maintain models (lack of computing resources), and iii) lack of expertise. In addition, Internet connection is considered a bottleneck in the spreading of new technologies.
- ✓ Dedicated training on hydroinformatics (including programming) in university courses and cooperation in joint international projects would help to create a generation of experts promoting digital groundwater governance in Africa.

Introduction

Groundwater importance in Africa

Groundwater is a resource of increasing prominence in Africa, whose potential has still to be developed in full capacity for multiple reasons: the natural storage is high, the water quality is often good, and infrastructure is more affordable than for surface water supply to poor communities (Adelana and MacDonald, 2008[1]). However, data on groundwater systems are sparse and the current state of knowledge is low, hence constituting a serious limitation to the sustainable development of these resources (Xu et al., 2019[2]).

While it is clear that data gathering and a proper level of knowledge is of outmost importance for many African aquifer systems, at the same time there is a need for Information and Communication Technologies (ICTs) that may improve data management. Their diffusion is nowadays facilitated by two main factors: availability of both computing resources at low cost and open source (OS) and free software.

The multifaceted objective of this research is to assess the state-of-the-art in groundwater management in Africa, through a review of digital and data-based governance toward improved sustainability, while devising needed capacity building actions in order to achieve the defined goals.

Why dealing with digital tools for groundwater management

Standardized and digitally referenced groundwater data are required to enable the detailed analysis of local, regional, country-wide and transboundary groundwater needs and trends; to prioritize issues, areas and techniques to focus limited resources on; to enable the prediction of future scenarios; and to investigate the linkages of groundwater to other environmental issues (such as surface water/groundwater exchanges for guaranteeing minimum environmental flows, sustaining groundwater dependant

[1] Adelana, S. M., & Macdonald, A. M., 2008. Groundwater research issues in Africa. Applied groundwater studies in Africa. Taylor and Francis, London.

[2] Xu, Y., Seward, P., Gaye, C., Lin, L., & Olago, D. O., 2019. Preface: Groundwater in Sub-Saharan Africa. Hydrogeology Journal, 27(3), 815-822. DOI: 10.1007/s10040-019-01977-2

ecosystems and wetlands, etc.). Here, we refer as digital tools to all those tools allowing groundwater data gathering, archiving and analyses, spanning from digital sensors, to Geographical Information System (GIS), numerical modelling up to advanced artificial intelligence methods for data-based groundwater resource planning and management.

Why using groundwater modelling as a proxy of digitalisation in the groundwater sector

GISs and spatial databases are consolidated and cross-cutting technologies, spread at global scale in the last twenty years, spanning through different fields such as the urban and environmental ones, as well as water management. On the other hand, the widespread adoption of groundwater flow numerical modelling is more recent and may provide better evidence of the late trends regarding the level of digitalisation in the groundwater sector, particularly in low income countries. Building groundwater flow numerical models has become easier in the last ten years at most organizations, whether in the private or public sector, e.g. governmental and academic/research Institutions. OS codes and even user-friendly modelling environments have become increasingly available. More advanced applications (i.e. Artificial Intelligence based methods) are still in their infancy in the water sector, both in academia and in applied research, even in high income countries. Hardly they could be considered a reliable proxy. Based on the reasoning above, our research focused on the trends over the period 2000-2020 in the use of groundwater flow numerical models and the further adoption of solute transport models.

Why modelling is an important tool

Physically-based and distributed groundwater numerical models (coupling ground- and surface-water and unsaturated zone processes, and incorporating climate, land use, hydrological and hydrochemical data) may constitute comprehensive and dynamic tools to target water resource management issues (Rossetto et al., 2018[3]). Numerical groundwater flow models are playing an increasingly important role in recent years. These tools allow simulating the distribution of the groundwater resource in space and time, taking into account anthropogenic stressors and providing sound-scientific information relevant to decision makers. They may support the development of highly informative representations of hydrological systems by: i) combining all the available spatial and non-spatial data in a single framework; ii) allowing their update as new data are gathered; iii) providing information in space and time to water managers; iv) offering relevant predictive functions, thus allowing evaluation on how a hydrological system might behave under different scenarios of natural and anthropogenic constraints. They may substantially help in supporting science-based decision making, by allowing at a first step water budget calculations, identification of most relevant inflow/outflow terms, as well as their spatial and time variations. Once understanding of a hydrological system is achieved and after calibration, models may be used for predictive simulations, leading to relevant information for the support of sustainable groundwater resources management policies (e.g. irrigation in agriculture, water use in industry and for human supply, availability in the context of climate change), and feasibility and assessment of large infrastructural projects (i.e. waterways, tunnelling, damming, contaminated aquifers remediation). A number of codes and related software, either OS, free or proprietary is available to assist the development of groundwater models and integrated hydrological models, as, among others, MODFLOW (and its entire USGS family), FEFLOW and Hydrogeosphere.

[3] Rossetto, R., De Filippis, G., Borsi, I., Foglia, L., Cannata, M., Criollo, R., & Vázquez-Suñé, E., 2018. Integrating free and open source tools and distributed modelling codes in GIS environment for data-based groundwater management. Environmental Modelling & Software, 107, 210-230.

Published research survey

We performed a comprehensive literature review on groundwater modelling by searching scientific databases for published papers (i.e. SCOPUS, Web of Science, etc.) and grey literature from 2000 to 2020 using relevant technical keywords associated to geographical ones. We found a total of 552 documents which included 339 scientific papers, 60 conference proceedings, 46 MSc thesis, 53 PhD thesis, 50 technical reports and 4 books. Considering the period 2000-2019, 60% of the documents were published in the last decade (2010-2019), with 34% being produced in the last five years. In 2020 alone, the number of released documents amounted to 8% of the total retrieved literature for the previous twenty years.

As not all of the technical reports, conference proceedings or theses may be easily available on the web (thus a part of the documents may have not been retrieved), we refer in the following analysis only to scientific papers, for which we assume to have performed an exhaustive search. During the period 2000-2019, the number of produced studies passed from 9% of the total in 2000-2005 to 38% during the 2015-2019 (Figure 1). Papers published in 2020 alone reached 14% of the total research papers published during the period 2000-2019. Most of the models are implemented in the following transboundary Aquifers Systems (AS): the Nubian Sandstone AS, the Northwest Sahara AS, the Irhaerzer-Iullemeden Basin, the Lake Chad basin, the Toudeni Basin, and the Senegalo-Mauritanian basin. Models are also being used in the SADC area (Figure 2). Still Equatorial Africa seems to be a poorly investigated area.

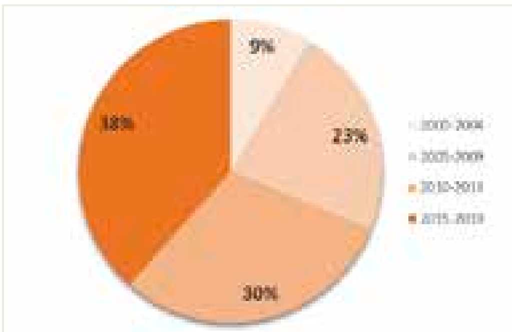

Figure 1. Percentage of scientific papers published per lustrum in the period 2000-2019 in the African continent.

A considerable number of studies (37%) has been led in 2000-2019 by scientists affiliated to non-African institutions. To avoid bias due to out-of-the-continent led interests, we focused only on the papers led by a scientist affiliated to an African institution. Figure 3 shows the number of papers with first author from an African institution versus those which are not African led, and those without African co-authors. To this regard, the African led papers increased about five times, passing from 16 in the period 2000-2004, to 78 in 2015-2019. We noticed a sharp divide between North Africa (NA) and Sub-Saharan Africa (SSA): the five North African countries contributed to 62% of the whole scientific production. African led studies are mostly run in Egypt, Tunisia, Morocco, Ghana, South Africa, and Nigeria.

Figure 2. Extent of modelled areas in Africa (2000- 2020).

Figure 3. Number of scientific papers with a scientist from an African institution as first author versus those not from an African institution.

A survey on the use of digital tools in the African continent

In order to get the view of African experts on the present use of digital tools and on future perspectives, we ran a survey (in French and English language). We structured a questionnaire in four sections with a total of 83 questions. The first section aimed at characterising the respondents, while the second collected background information on the issues faced. The third section was devoted to groundwater monitoring and sampling practices, while the fourth and last one focused on the use of modelling and digital tools for groundwater resource management.

We submitted more than 800 dedicated requests and received 220 completed questionnaires from experts dealing with digital tools in groundwater resource management (largely with a PhD title, 66%). About 90% of the interviewed ones declared to use digital tools for groundwater resource management daily. They represented 175 institutions (mainly universities and research centres, but also governmental institutions) from 41 African countries. We received answers from 10 or more respondents from ten countries (Algeria, Cameroon, Egypt, Ethiopia, Kenya, Morocco, Nigeria, Senegal, Tanzania and Tunisia). Figure 4 shows the main interest of the interviewed sample for each groundwater resource management area (2 answers per participant were possible). Figure 5 shows the respondents self-evaluation on the degree of expertise on GIS, numerical modelling and digital tools for advanced statistics (1= low, 5= high).

The interviewed agree on the fact that the use of digital tools is relevant, as they may provide a dynamic and easily updatable view on the resource available, used, and potentially exploitable without the need of relying on analogical or paper-based static analyses.

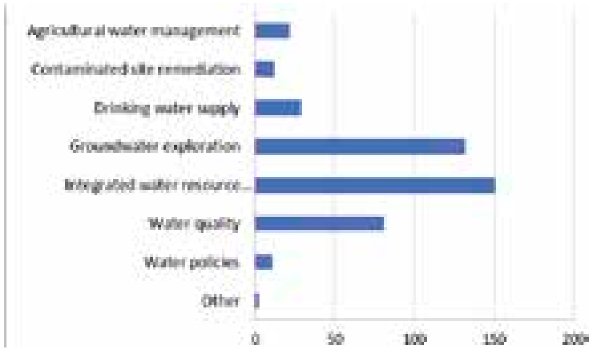

Figure 4. Areas of interest in groundwater resource management for the interviewed sample.

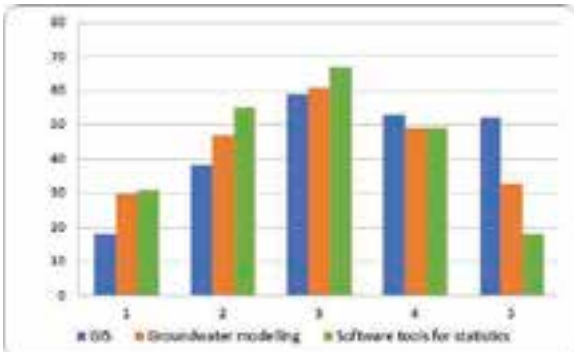

Figure 5. Self-evalution of the degree of expertise of the respondents.

Digital tools are recognised as needed tools for groundwater resource management at national/regional level in African countries by about 60% of our sample, while only 10% of them believe that adequate importance is not given to these tools. The remaining 30% of the interviewed ones do not have a clear opinion about it. These tools are mostly used with the objective of achieving sustainable groundwater management, hydrodynamic/hydrochemical characterisation of groundwater bodies, and defining the most productive areas of aquifers.

According to the respondents, groundwater numerical modelling and/or other digital tools are still mostly used in the academic/research environment for research purposes (43%), while 30% of the respondents believe these tools are well-tailored for use in professional work. Usage by public authorities is still emerging (14%). These tools are regarded to improve groundwater resource management, as they may first support data-based decision making (70% of the respondents). Secondly, they may provide insights for planning adaptation measures to climate change (49%), increase the value of data gathered at monitoring networks (47%), and also help the design of engineering projects (including land contamination and remediation; 45%). However, the use of groundwater numerical models is deemed to be an occasional activity by about 50% of the respondents. The 30% of the sample reports that models are mostly applied for large engineering projects, and used on a routine basis only by 10%. Once built, these models are not updated regularly (for 45%), or even abandoned (for 32%), meaning they are not regularly used for groundwater planning and management.

The most used digital tools for groundwater resource management are: calculation spreadsheets, then GISs applications, followed by numerical modelling tools (with only half the number of users than the previously mentioned tools) and, finally, advanced tools for statistical analyses. At about 85% of the institutions interviewed, there is at least one expert in GIS (with ESRI ArcGIS being the most diffused application, 97%, followed by the OS QGIS, 77%). Notably, 63% of the institutions have at least one expert in groundwater numerical modelling, with 50% having also at least one person dealing with contaminant transport. Most groundwater modelling graphical user interfaces (GUI) are commercial ones (Visual MODFLOW, followed by AquaChem, GMS, FEFLOW, and PMWIN). The first mentioned OS modelling suites are MODELMUSE and FREEWAT, but the two were chosen by less than 10% of the respondents. Unfortunately, the respondents did not provide useful replies regarding the average computational capacity at their institutions.

The 76% of our statistical sample agrees on the fact that groundwater models, even built with scarce data, are valuable tools to drive hydrogeological investigations and to get initial insights on the spatial distribution of resources. On the importance of data gathering and simulation models, 52% of all the respondents are convinced that prior to any modelling exercise starts, a robust data collection effort should be undertaken.

The way forward

The conducted research allowed a detailed overview of the use and diffusion of digital tools for groundwater resource management in Africa. Both the literature review and the survey run show that they have entered and are progressing in the African context. This increasing trend was still ongoing in 2020. However, out of these data, we may say that the present usage of digital tools is in general still low. Many of the retrieved scientific papers deal with basic applications by means of commercial GUIs, providing the idea of usage driven by software availability on the market, rather than a consolidated methodology. This is also confirmed by the fact that, when asked about available computing capabilities, a large part of the interviewed sample did not provide such information. A single example of active software development was retrieved in the documents search. This progress in digitalisation is faster in NA than in SSA. Within SSA differences also exist. For example, South Africa and Ghana seem to be more advanced, while in other countries we do not have this evidence. At the same time, not all the countries of similar areas share the same level of advancement (i.e. in Western Africa, Senegal seems to be more advanced than Mauritania, Gambia and Guinea Bissau).

A particular focus was dedicated to review the use of OS tools. At present, the digital groundwater management is still dominated by commercial applications. Anyway, the declared use of free and OS GIS applications and the appearance of free and OS GUIs for modelling shed a light on an increasing trend of usage. Only 22% of the whole sample consider that, on average, skills and capacities for digital groundwater management are available in their own country, while it is the opinion of 50% of the respondents that these are not reached. The three key elements identified as barriers in the use of digital tools are: i) scarcity of data, ii) inadequate financial resources to develop and maintain models (lack of computing resources), and iii) missing capacities (including lack of computing skills). Finally, the lack of adequate and well-functioning Internet connection is considered one of the main bottlenecks against the spread of new technologies.

Capacity building on the use of digital tools is deemed to be extremely or highly necessary (60% and 35%, respectively). Undertaking cooperative international research projects is considered the most relevant action to create capacity, followed by training and national projects. Capacity building and knowledge transfer have then to be on top of the agenda for achieving a digital groundwater governance in Africa. We suggest to introduce applied courses on hydroinformatics, at university level (both in BSc/MSc and in PhD degrees) where fundamentals of programming are taught and then move to more applied contents. In particular, training should be directed to favour the use (and re-reuse) of OS applications and the huge amount of information and contents freely available. This will allow young professionals/researchers to be aware of the methods independently from commercial software, to be able to choose among the solutions that fit best, and to modify and tailor them for their own purposes.. A generation of experts with a sounding interdisciplinary background should be able, in five to ten years, to properly drive digital groundwater governance in Africa.

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SCIENCE BEHIND THE DEBATE

Healthcare and WASH versus COVID-19 outbreak in Africa

Key points

✓ Since 2000, the vulnerability of the overall African continent to respiratory diseases decreased. However, infections and concretely lower respiratory infections remain high and account for 10.4% of total deaths, reaching up to 916,851 deaths in 2016[1] across the continent. In the context of COVID-19, these are important factors to consider.

✓ Disparities exist across the continent: 55% of countries (Class C-2016) are considered the most vulnerable to mortality due to lower respiratory diseases because they show the lowest life expectancy, weakest healthcare system and limited WASH services, highest mortality rates and lowest rates of urbanization and migration remittance inflow.

✓ Official Development Assistance (ODA) does not appear to be associated with reduced vulnerability to respiratory or infectious diseases at the country level, but its potential positive impact can be observed on a smaller scale (to be further studied).

✓ Remittance inflows coming from national diaspora appears positively associated to lower mortality and better access to WASH services.

✓ Additional efforts to increase access to water, sanitation and handwashing as a result of the COVID-19 pandemic, could also impact other prevalent diseases that contribute to high rates of mortality in Africa, such as diarrhoea (7.4%), malaria (4.6%) and tuberculosis (4.6%), which accounted for as many as 2,383,263 deaths (27% of total deaths) in 2016 (WHO, 2018).

Introduction[2]

As the COVID-19 crisis spreads around the world, it is essential to build on the experiences and lessons learned from China and Europe in the fight against this pandemic at a very high cost in human lives, as well as the hard-won experience in Africa from the recent Ebola and preceding cholera outbreaks. One of the lessons learned has been that those with the least access to essential services such as water, sanitation and hygiene will probably feel the most dramatic effects. An act as simple as frequent hand washing for at least 20 seconds could prevent the dramatic spread of the pandemic among the population[3]. Although indoor and outdoor air quality are the main environmental factors related to lower respiratory infections, the lack of access to handwashing facilities is also recognised as a contributing factor in the case of lower respiratory infections, which are a leading cause of morbidity and mortality around the world.

From this particular crisis, we have come to understand that public health depends on the security of water resources for all (Sustainable Development Goal 6 - SDG 6). Preventive measures are aimed to slow down the spread of COVID-19 virus, thus reducing the number of critically ill patients and providing precious time to increase hospital capacity. Such a strategy presupposes that at least three conditions are possible to put in place: 1) social distancing; 2) access to clean water and soap; and, 3) that the health care sectors are able to increase their capacity for treatment of respiratory illnesses in a short period of time. These three assumptions are very complicated even for the wealthier developing countries such as those on the continent of Africa.

It is well known that 3 billion people, or 40% of the world's population, do not have access to basic handwashing facilities at home. In this context, expanding access to water becomes essential, but there is also an urgent need to create more resilient communities confronted by the fundamental problems of water insecurity. Without basic measures to build resilience, the growing pandemic could be especially difficult to control in developing countries, with the high risk of becoming a global resurgence of the problem.

A fundamental question to be addressed is how the transmission of COVID-19 could unfold in an African context, given its high levels of poverty, weak health systems and overpopulated urban areas. The virus could be particularly devastating, even with Africa's past experience in fighting infectious diseases an epidemics such as Ebola and cholera outbreaks as well as diseases from water-related vectors such as malaria. For vulnerable members of the population (ill, very young or very old) it has been shown for example that caregiver handwashing with or without soap after defecation and washing of the child's hands with soap before feeding were predictive of RTI prevalence among the children (Fadilatu et al., 2019). Indeed according to the Infectious Disease Vulnerability Index, 22 of the 25 countries most susceptible to an infectious disease outbreak are in Africa.

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[1]WHO (2018). Global Health Estimates 2016: Disease burden by Cause, Age, Sex, by Country and by Region, 2000-2016. Geneva, World Health Organization; 2018.

[2] Full list of references, variables and analysis in C.Carmona-Moreno, P.Marcos-Garcia. Analysis of the spatio-temporal evolution of Healthcare and WASH services and influence on the total and lower respiratory infection deaths in Africa (2000-2016). JRC Technical Report (2020).

[3] WHO/UNICEF (2020). Water, sanitation, hygiene, and waste management for the COVID-19 virus Interim guidance 19 March 2020.

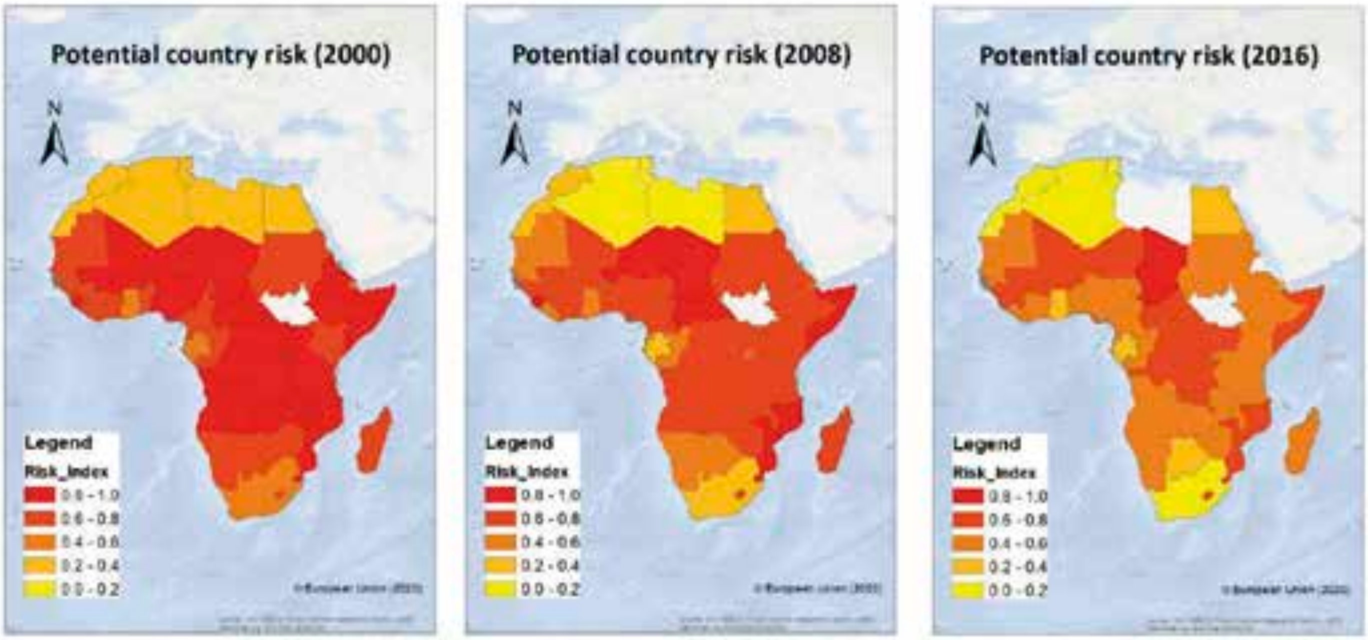

***Figure 1**. Estimation of a Potential Risk Index based on the Spatio-temporal evolution (2000-2016) of Healthcare and WASH services and their influence on the total and lower respiratory infection deaths in Africa.*

In this short note, we aim to outline African country profiles regarding the implementation of WASH and Healthcare services and other socio-economic aspects in relation with the mortality of endemic lower respiratory infections. The objective is not to analyse the full multi-causality of such death diseases, but the potential vulnerability of African countries to COVID-19 and its potential expansion due to weak Healthcare and WASH systems in Africa as can be deduced from the analyses of 17 years of data (2000-2016).

For this study, the annual data of 16 variables for the period 2000-2016 at the national level were retrieved from different sources. Incomplete data regarding handwashing facilities were estimated using basic sanitation and drinking water services as explanatory variables in a linear regression model.

The Principal Component Analysis (PCA) is an exploratory statistical tool that identifies the most significant variables in a dataset. Our goal is to analyse the correlations between the different variables and to find out if the changes in variables related to mortality (total and lower respiratory infection deaths) during the selected period are linked to the development of Water Access, Sanitation and Hygiene (WASH) services, social changes (Population density, Urban population) and economic conditions (GDP, Migrant remittance, ODA). The three first components in our analyses explain up to 78.86% of the variability of the dataset.

As shown in Table 1, PCA1 (the first component) is related to access to and quality of health care, basic sanitation, migrant remittance flows, urban population, life expectancy and (negative correlation) total number of deaths in the country. To be noted that from Table 1, it appears that these variables are not significantly linked to ODA (official development assistance). This component can thus constitute an index showing the risk of mortality in the countries and thus to the life expectancy in the country as a function of the quality of health care, basic sanitation, urban population and migrant remittances.

PCA1 is then used by the K-Means and ACH (Agglomerative Hierarchical Clustering) algorithms to determine homogeneous groups of countries with similar profiles over the 17 years of data by linking the development of WASH services with (formal and informal) investments and respiratory diseases.

In 2016, three groups of countries[4] in Africa have been identified: **Class A-2016** countries show the highest life expectancy, strongest healthcare system and WASH services, lowest mortality rates and highest rates of urbanization and migration remittance inflow; while **Class C-2016** countries, show the lowest life expectancy, weakest healthcare system and WASH services, highest mortality rates and lowest rates of urbanization and migration remittance inflow. Therefore, it could be hypothesised that **Class A-2016** countries are in a *better position to tackle public health emergencies*, while Class **C-2016** countries could be *the most vulnerable one*[5].
The remainder of the countries are in **Class B-2016**, which shows intermediate values of these variables. The countries in these classes are:

- **Class A-2016** (*best position to tackle public health emergencies*): Algeria; Mauritius; Seychelles; Egypt; Libya; Morocco; Tunisia; Cabo Verde.
- **Class B-2016** (*intermediate capacity countries*): Botswana; Sao Tome and Principe; South Africa; Gabon; Rwanda; Comoros; Namibia; Senegal; Djibouti; Ghana; Sudan; Gambia; Kenya; Equatorial Guinea; Madagascar; Malawi; Tanzania; Uganda; Zambia; Ethiopia.

[4] South Sudan – No historical data for a significant analysis and classification. Lybia - no data from 2011 in advance.

- **Group C-2016** (*the most vulnerable countries*): Central African Republic; Chad; Sierra Leona; Somalia; Niger; Lesotho; Mali; Burkina Faso; Democratic Republic of the Congo; Guinea; Côte d'Ivoire; Cameroon; Mozambique; Nigeria; Eritrea; Benin; Guinea-Bissau; Togo; Burundi; Angola; Eswatini; Congo; Zimbabwe; Liberia; Mauritania.

Discussion

Our analyses show that any reduction in mortality in a country, in general, and in respiratory diseases in particular, is associated with increased investments in basic sanitation (population with basic handwashing facilities, including soap and water, basic drinking water and basic sanitation services). Based on the analyses, it could be hypothesised that the Official Development Assistance (ODA) does not have a sufficient impact on improving sanitation services and thus on reducing mortality related to respiratory diseases and, therefore, to increase life expectancy in developing countries. In this case, the flow of ODA to the sanitation sector may not be sufficient to improve the overall national sanitation structure, but may rather have an impact at the individual level that is not visible at the country scale as it should be (further analyses need to be explored to explain this point). However, the migration remittance inflows seem to have an impact on improving sanitation in households and local communities, even if its structure is not efficient enough.

As suggested by WHO in 2020, it is necessary to send short-term development assistance to improve health diagnosis of infected individuals and protect the local health population and, secondly, to strengthen the healthcare structure not only in the specific case of the COVID-19 pandemic but also to continue the treatment of the other infectious diseases that are ravaging African countries every year.

In Sub-Saharan Africa, several high-mortality pathologies (apart from COVID-19) are prevalent: malaria, bacterial infections, tuberculosis, AIDS... The number of deaths in Africa due to these endemic diseases represents around 27% of the total[5]. In 2016, the endemic diseases were equal to 2,383,263 distributed as follow: Lower Respiratory Infections (916,851 deaths – 10.4%), Diarrheal Diseases (652,791 deaths – 7.4%), Malaria (408,125 – 4.6%) and Tuberculosis (405.496 – 4.6%).These diseases are treatable and partly preventable, but their incidence could rise if most resources are directed to the COVID-19 outbreak. Indeed in the case of Ebola in 2014, it was estimated that malaria cases could have increased by up to 1 million as a result of a cessation of distribution of insecticide-treated mosquito nets. The solution could be to take advantage of economies of scale in current investments in health, to also combat other African endemic diseases such as diarrhoea, gastrointestinal diseases and tuberculosis.

The analysis of the 2000 - 2016 time series (Figure 2 – the potential risk in 3 different years: 2000, 2008, 2016) shows that even if the potential risks for African countries have decreased from 2000 to 2016 (see also Figure 1), they are far from being able to manage these endemic diseases and specifically lower respiratory infections. **Central and West African countries are particularly at risk together with Mozambique, Somalia, Lesotho and Eswatini**. According to our analysis, the **Central Africa Republic and Chad** could be the most vulnerable countries to the COVID-19 outbreak given the quality and performance of their health care system and WASH services.

	F1
Population_Urban	**0.621**
Population_Age	**0.868**
Life_Expectancy	**0.875**
Total_Deaths	**-0.783**
HAQ_index	**0.917**
Basic_Sanitation	**0.841**
ODA	0.031
GDP	0.200
Mig_remit_inflow	**0.684**

Table 1. Contribution of the Variables to the PCA1 (F1) component. The higher the variable value (max= 1), the higher the contribution to the PCA explaining the variability of the dataset. The negative value represents the sign of the correlation. In this case, the total number of deaths is highly correlated with the other variables in the PCA, but with a negative ratio, i.e. the higher the basic sanitation, the lower the number of deaths in the country.

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[5] WHO (2018). Global Health Estimates 2016: Disease burden by Cause, Age, Sex, by Country and by Region, 2000-2016. Geneva, World Health Organization; 2018.

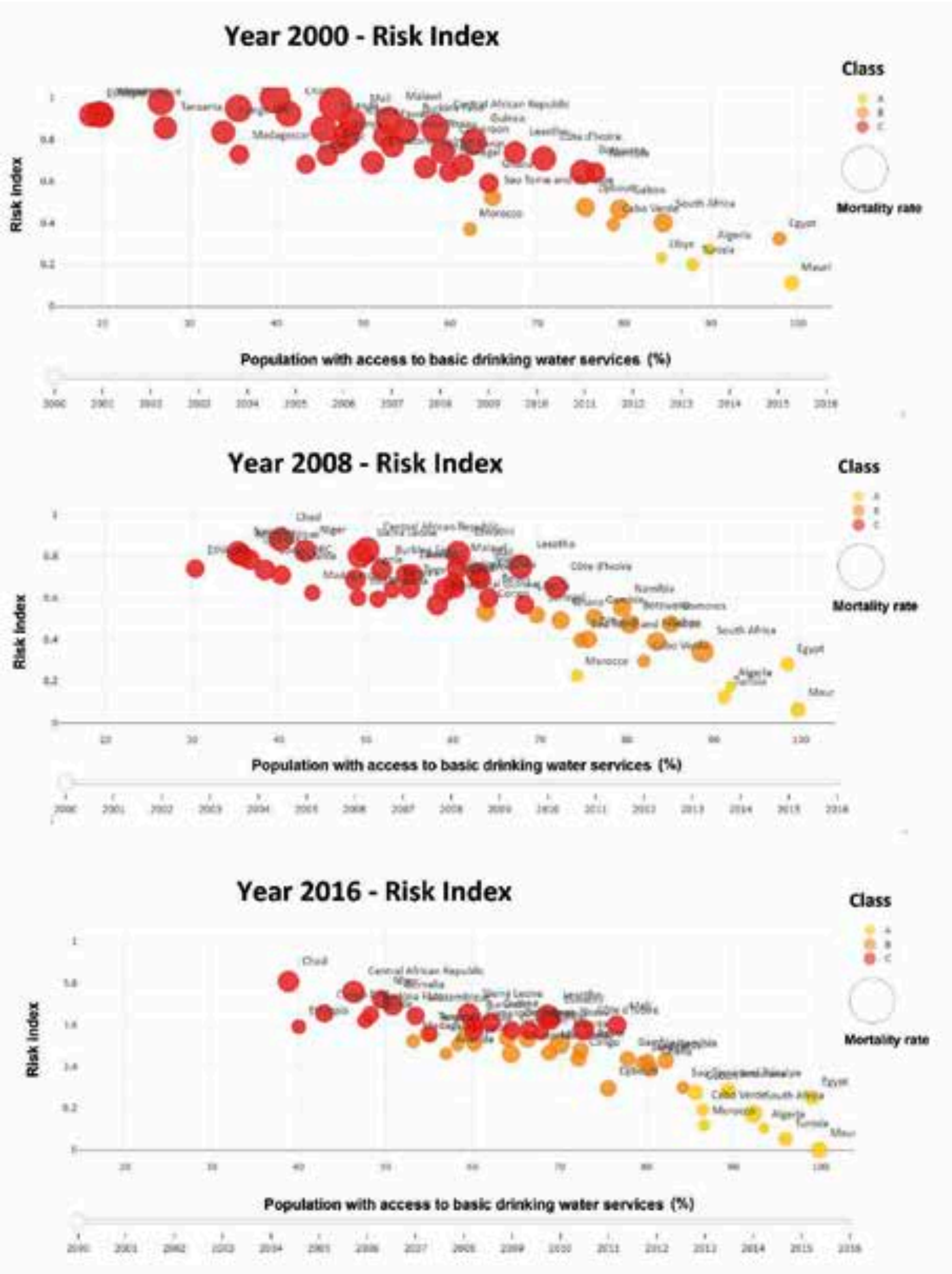

__Figure 2__ represents the potential risk (1 – __Highest Risk__; 0 – __Lowest Risk__) of the African countries to face Total and Lower Respiratory Infection deaths considering the quality of the Healthcare System and WASH services in 2000, 2008 and 2016. The colour of the circles represents the classes (A, B, C) and its dimension is related to the total number of deaths per year.

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