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Factors facilitating sustainable scientific partnerships between developed and developing countries

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Abstract

International scientific partnerships are key to the success of strategic investments in plant science research and the farm-level adoption of new varieties and technologies, as well as the coherence of agricultural policies across borders to address global challenges. Such partnerships result not only in a greater impact of published research enhancing the career development of early and later stage researchers, but they also ensure that advances in plant science and crop breeding technologies make a meaningful contribution to society by brokering acceptance of emerging solutions to the world problems. We discuss the evidence showing that despite a lack of funding, scientists in some African countries make a significant contribution to global science output. We consider the criteria for success in establishing long-term scientific partnerships between scientists in developing countries in Southern Africa ("the South") and developed countries such as the UK ("the North"). We provide our own personal perspectives on the key attributes that lead to successful institutional collaborations and the establishment of sustainable networks of successful "North-South" scientific partnerships. In addition, we highlight some of the stumbling blocks which tend to hinder the sustainability of long-term "North-South" scientific networks. We use this personal knowledge and experiences to provide guidelines on how to establish and maintain successful long-term "North-South" scientific partnerships.

Keywords

"North-South" scientific partnerships, societal acceptance, dissemination of information

Introduction

International partnerships in basic and applied science are key to the sharing of knowledge, technologies and experience. Moreover, they are a key driver for successful translation of new knowledge to the farmer and agro-industries, as well as the successful development of up-to-date research environments in developing countries, which are often at the frontline of the consequences of global challenges such as climate change. Societies in both developed and developing economies remain uncertain about embracing technologies, such as gene-editing, for building climate change resilient-crops. International partnerships can foster societal acceptance, a necessary condition to regulatory approval and investment. Next generation sequencing technologies provide unprecedented possibilities for reconstructing the complex genomes of crops and powerful new genome editing technologies, such as CRISPR/Cas, allow the targeted modification of genes necessary to engineer entirely new traits and preferred trait combinations thus overcoming the incompatibility barriers between species (Bailey-Serres et al., 2019). The adoption of these high throughput technologies in international scientific partnerships encourages multidisciplinary research approaches and greatly the capacity to extend new knowledge, as well as publishing and the applying the outputs from research. The

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impact of published research is considerably enhanced providing unprecedented possibilities in the fight for resilient high-yielding crops. Moreover, international partnerships can become important actors in the dissemination of information that satisfies societies' renewed interest in agriculture and alleviate public unease about "incomprehensible" scientific innovations that are deeply rooted in consumers' intrinsic care about the food supply (Adams and Loach, 2015). If successful, such partnerships can be the driving force behind successful policymaking and the associated and much needed private and public investment in plant science research.

Scientific partnerships considerably enhance the competency, skill sets and knowledge (including traditional knowledge, local experience and know how) of the participating scientists. Multidisciplinary partnerships greatly strengthen the scientific activities of all the participants and their technical capabilities by enhancing human-centered design (HCD) pipelines, as well as research breadth, standards and quality. They are the drivers for employment and economic development by facilitating rapid capacity building. The promotion and support of international scientific partnerships is therefore high priority for most countries. Successful outcomes, however, are often determined by the socioeconomic wealth and scientific activities of the scientists in each country. The scientists are ultimately the real "actors" and "facilitators" of these partnerships, as they very often initiate partnerships by setting up informal contacts and acquaintances. However, all too frequently the scientists have no basic training in how to establish sustainable long-term partnerships that will have the durability to facilitate real benefits to society beyond the lifetime of the initial contracts. If we have learnt anything from humanities efforts to continue to function during the COVID 19 crisis, then it is that current globalization trends and available information and communication technologies and distance is making no longer a stumbling block to engaging in international partnerships. The participating institutions must have the capacity to provide the required infrastructure, as well as the essentially equipment, laboratories and facilities, as well as the legal frameworks required to realize successful scientific partnerships. In this article we provide perspectives and guidelines based on our own experience of the factors to be considered when establishing scientific partnerships with African countries. We highlight the potential hurdles that have to be overcome in order to establish successful long-term, sustainable scientific partnerships.

African Science and international partnerships

It is generally accepted that scientific partnerships are invaluable to capacity building and greatly beneficial to the exploration of new scientific endeavors. However, the establishment of sustainable scientific partnerships with African colleagues is often challenging. This can be due to many factors, such as political instability and civil wars, colonial scientific legacies; structural adjustments and economic decline, together with a continuation of brain drain that are beyond the control of the immediate partners (Mouton, 2018). However, many such initiatives focus too much on immediate scientific goals and they fail to identify the key aspirations, needs and requirements of each partner for both short and long-term sustainability. For partnerships to be sustainable, they must be built on mutual respect and shared knowledge. They should be fair and equal with respect to ownership and beyond, in order to strengthen capacity, improve development and promote scientific outcomes (Carbonnier and Kontinen, 2014).

Table 1. Global expenditure into research and development by region (2011)—billions of US purchasing power parity dollars.

Region	US PPP dollars	Percentage of PPP dollars (%)
Africa	11	0.8
Asia (Total)	527	36.7
Central Asia	35	2.5
East and Southeast Asia	456	31.8
South Asia	36	2.5
Australia and Oceana	24	1.6
Europe	345	24.0
Middle East	31	2.1
Americas (Total)	498.6	34.7
Central America and the Caribbean	0.6	<0.1
North America	462	32.2
South America	36	2.5
World total	**1,435**	

Fairness and equitability is often a concern for the African partners, who often suffer the negatively impacts of a lack of funding. Governmental investments in research and development (R&D) expressed as proportion of gross domestic product across Africa averages between 0.2% and 0.3% (Table 1). This low investment in R&D makes African scientists highly dependent on foreign funding to support research activities (Mouton, 2018). This funding is often skewed by the investors interest (i.e., mostly toward health—and agricultural related fields) rather than the needs of the local communities and researchers. Inadequate funding has negative impacts on the quantity and quality of research outputs because it results in a lack of infrastructural support, minimal access to new technologies and hence, the low novelty and competitiveness of outputs, which in turn leads to poor publication records and limited access to scientific journals (Langer et al., 2004).

A recent survey reported that apart from South Africa and Tunisia, most research in Africa is still supported by funding agencies based in Europe, the United States and China (Figure 1). Private investment and funding from the National Research Foundation of South Africa are the biggest contributors to research funding in South Africa, while Tunisia's science ministry makes a significant contribution to research funding in Northern Africa. Research in most other African countries depends almost exclusively on funding agencies based outside the continent, because national organizations are unable to give sufficient support to research activities that would assist in the establishment or

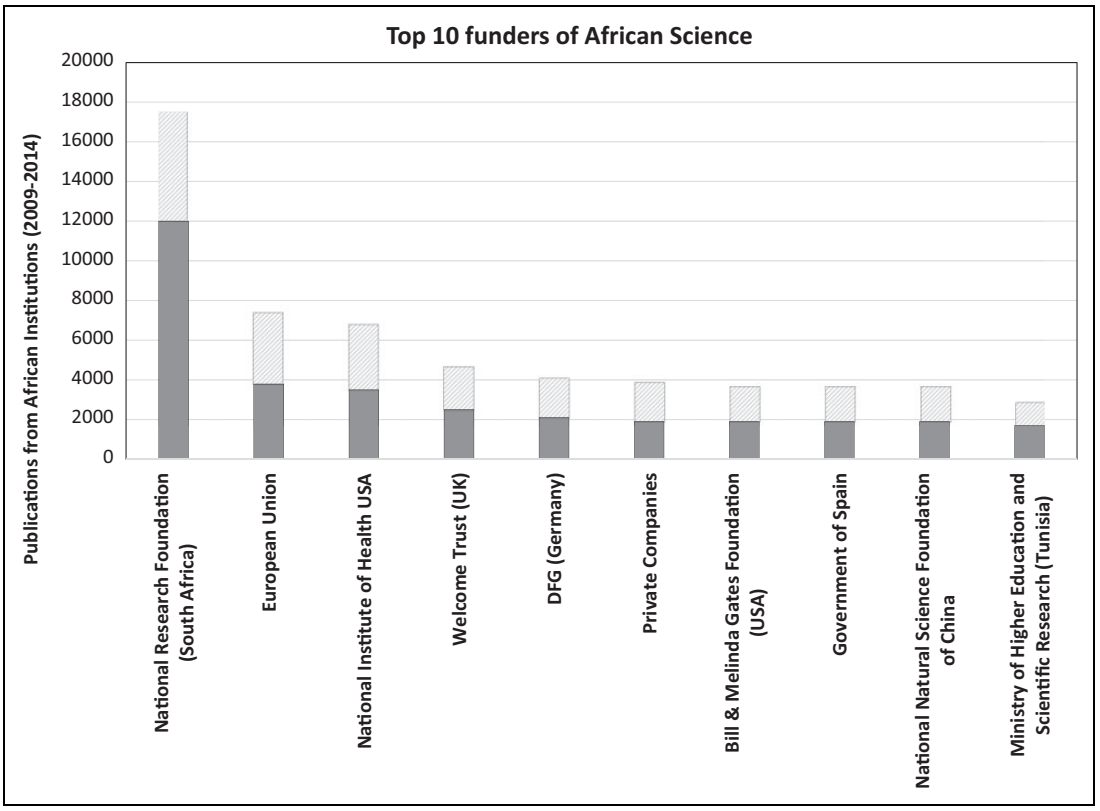

Figure 1. Investment into research and development as reflected by acknowledgments in publication outputs—only top 10 investors (Modified from Omungo, 2018).

maintenance of international scientific partnerships (Mouton, 2018; Omungo, 2018). The EU supports research in Africa through different research and innovation platforms, as well as research capacity building programs such as RISE (Research and Innovation Staff Exchange) and IRSES (International Research Staff Exchange Scheme). Other EU platforms include the European Development Fund, which supports research in Africa through the African Union platform (i.e., ACP Research Programme for Sustainable Development). Over the past decade the African Union in partnership with the EU has invested over $US20 million in research, of which about 7 Million has supported R&D projects related to agriculture (African Union, https://au.int/sites/default/files/newsevents/workingdocuments/27671-wd-23_-_aurg-booklet-draft-v3_0.pdf). A prevailing problem with such funding models however, is that most financial donors still apply demand-driven approaches and mainly support African priorities defined by donors. These donors are often constrained by government priorities and they do not fund essential underpinning innovative research that would drive African science forward and create the essential cohort of highly trained and internationally completive African researchers that would form the backbone of next generation science in Africa. For example in the agricultural field, such funding restrictions mean that most African scientists are forced work on crops that are perceived important by the local donors or governments. This emphasis can be a severe impediment to knowledge generation, not least because such donor-imposed constraints may neglect other local crops that could answer important research questions and that may also add value in terms of food security.

Although scientists working in agriculture may have access to international research funding, the number of scientific partnerships with Europe is generally much lower than in political or medical science fields, despite the importance of agriculture to African economies. For example, academics affiliated with the University of Pretoria in South Africa participated in 21-EU-funded projects in the field of Natural/Agricultural Sciences from 2006–2019, of these 14 were within the category of Agriculture/Plant Sciences. However, only one project was coordinated by the University of Pretoria, the rest being under the coordination of an EU partner. Also, in all these partnerships, limited funding (from 50-100,000 Euros) was distributed to the African partner. Similarly, academics from Stellenbosch University, another leading academic institution in South Africa, were participants in 13 EU-funded Agriculture/Plant Science-related projects since 2014. Again, coordination was undertaken by the EU partners, with minimal funding allocated to Africa. Many EU-funded initiatives, such as the European Cooperation in Science and Technology COST program, are co-funded by the Department of Science and Technology in South Africa and they are designed to establish global scientific networks and aim to establish longer-term scientific partnerships.

The UK Development Partnerships in Higher Education (DelPHE) (https://www.britishcouncil.org/partner/track-record/development-partnerships-higher-education) seeks

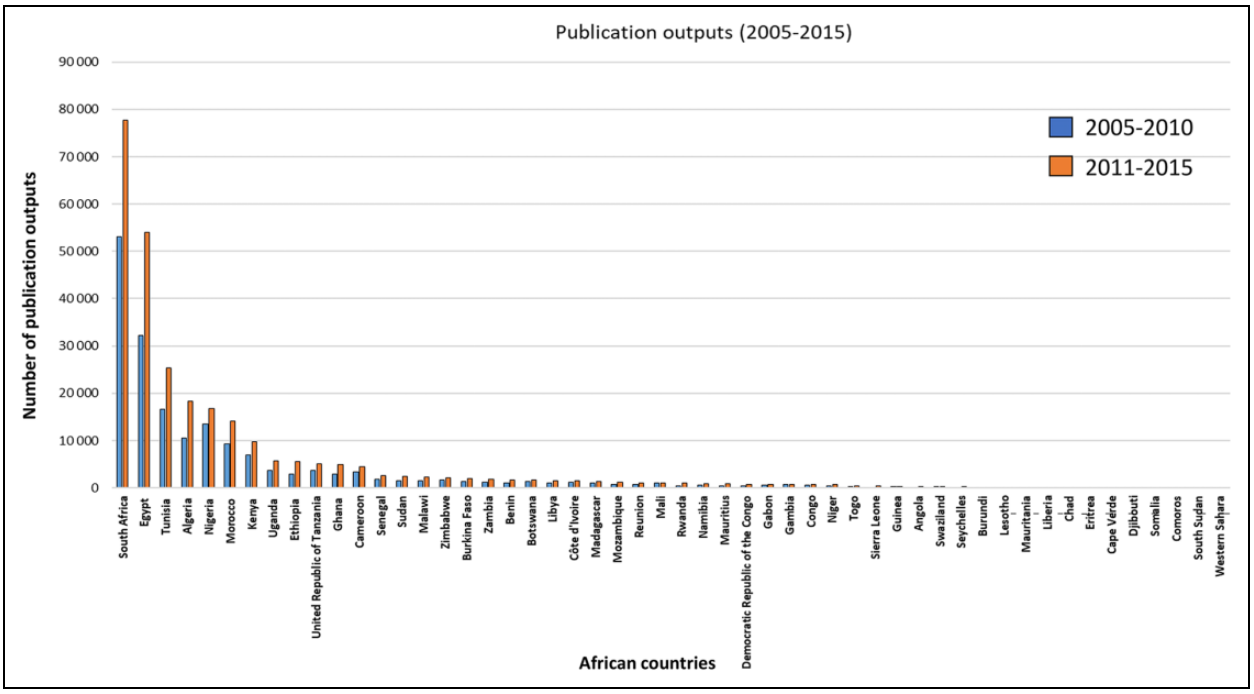

Figure 2. Bibliometric data indicated a substantial increase (± 33%) over 5 years (i.e., from182,177 for the period 2005 to 2010 to 275,466 for the period 2011 to 2015, with six countries (South Africa, Egypt, Tunisia, Algeria, Nigeria and Morocco) contributing approximately 74% of all the outputs from the continent (Modified from Mouton and Blanckenberg, 2018).

to establish partnerships between scientists in the UK and Africa. A key aim is to strengthen the capacity of higher education institutions so that they could achieve the Millennium Development Goals. Germany promotes partnerships between German and African scientists, particularly in countries such as Namibia and South Africa, under the umbrella of sustainable use and conservation of biodiversity in Africa, in the program BIOTA AFRICA (http://www.biota-africa.de/index.php?Page_ID=L900). However, the number of scientific partnerships originating from such R&D and/or network programs is generally still low in sub-Saharan Africa. Moreover, South Africa makes a significant contribution to these international scientific partnerships (Leydesdorff et al., 2013). The low number of international partnerships with Africa is also clearly reflected by the small percentage of international exchanges supported by the Royal Society, UK, which is one of the largest European supporters of international scientific exchange programs globally. For example, between 2011 and 2017, only 2.6% Royal Society supported exchanges took place between the UK and African countries compared with 38% with Asian countries (https://royalsociety.org/grants-schemes-awards/grants/international-exchanges/).

Bibliometric data accumulated over the past decade indicates that research outputs increased significantly (± 33%) in Africa. For example, 182,177 outputs were recorded for the period between 2005 and 2010, while 275,466 research papers were published from 2011 to 2015. It is worthy of note, however, that approximately 74% of all the outputs originated from only six countries (i.e., South Africa, Egypt, Tunisia, Algeria, Nigeria and Morocco) on the continent (Mouton and Blanckenberg, 2018) (Figure 2). Interestingly, an analysis by the same authors revealed that African scientists contributed more papers than the overall world average (3.2%) in 86 of the total of 273 subject categories in The Web of Science. Crucially, African researchers made a significant contribution to global output (more than 4%) in nine fields i.e. tropical medicine; parasitology; infectious diseases; public, environmental and occupational health; water resources; ecology; immunology; zoology; and plant sciences. These results clearly reflect realities and priorities in the African continent including the extreme richness in biodiversity, and the urgent need to invest much effort in the study of tropical diseases that plague many African countries (Figure 1). There is also a direct correlation between R&D investment and the success of research activities. Countries with a stronger R&D investment, whether via direct Government investments (South Africa and Tunisia) or via foreign funding tend to be more productive over a 10-year period (Figure 3). These countries also traditionally have stronger international scientific partnerships with funding from outside Africa. This provides a firm foundation for the observed contribution of double the amount of scientific papers, compared to the number of outputs produced by researchers with no international funding support.

Contributors to a successful partnership

Choice of the scientific partner

There are several reasons why it is beneficial for a scientist working in the "North" to interact with African scientists particularly in the field of Agricultural and/or Pant Sciences/Biodiversity. Scientists in the "North" might, for example, have better access to the specific environments existing in

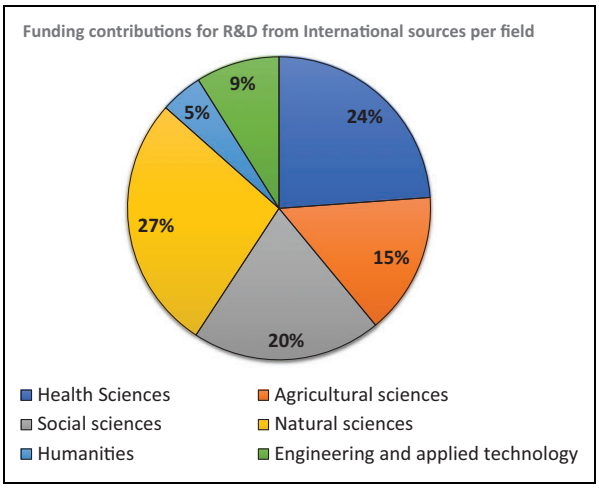

Figure 3. Investment into research and development expressed per field (Modified from Mouton and Blanckenberg, 2018).

Africa, with field studies and open air laboratories or other natural resources in the "South" for their research that is not available in the "North." For example, the access to the African flora or pests and diseases that are not available in their own countries or regions, are key drivers for a "North-South" scientific partnership. Since Africa is certainly no longer perceived as the "dark Continent," scientists from the "North" might also be interested to tap into local indigenous knowledge, such as natural resources, resource management ensuring food security and traditional practices that are not available in the "North." However, it is crucial that the partner in the "South" is equal in status and in that realization of the outcomes of the scientific partnership and not simply the provider of a specific resource. For example, factors such as providing an interesting species, allowing field trials in the "South," that are not allowed in the "North," or simply filling a place in a proposal so that the partner in the "North" has a better chance of success are unlikely to result in a long-term successful scientific partnership. Balancing the needs, aspirations and interests of all the scientists in such partnership is, however, not a simple task. It is particularly challenging when the funding is unequal between partners, and if for example most of the funding is retained by the institution from the "North" (Blagescu and Young, 2005; Bradley, 2008). Financial models differ between institutions but many universities and other organizations in Africa do not have the financial means to absorb and/or support research for interim periods for example while awaiting the release of funding. Such factors slow down the production of deliverables and result in conflicts in due dates/expectations.

The most successful scientific partnerships often have spontaneous origins (e.g. an informal conversation at a scientific meeting or conference or simply during a research visit). Spontaneous personal interactions and informal encounters are an important part for initiation and development of sustainable scientific partnerships. In contrast, perseverance, fortitude and good relationships are required to sustain partnerships over long periods, with consistent and regular face-to-face interactions (through on-line systems or otherwise). Face-to-face meetings are particularly helpful in ensuring efficient organization and problem solving. In person meetings can be costly but they are important for example to visit field experiments, and partners should therefore be willing to invest funds into preserving key partnerships.

From our experience, no scientific partnerships are plain sailing, because they face constant challenges and risks. It is thus important to always consider the costs, benefits and added value that accompany such scientific partnerships. All partners must understand the risks involved in any "North-South" scientific partnership at the outset, as well as the personal interests of the partners. Risks should never be underestimated. Partnerships are not driven only by the skills, reputations and innovative ideas of individuals, but rather by the complementarity of their interests, knowledge and skill sets. Partners should be willing and able to share infrastructure and data, and to strive for joint publications. All partners should also consider the needs and the advantages of any planned partnership carefully in advance of any commitments. Mutual trust and respect based on a shared scientific vision and agreed common goals is vital to the success of any partnership. Furthermore, any interaction with a partner who does not bring additional or useful expertise and resources to the table is doomed to fail. Successful partnerships can sometimes prevail over long periods with very little funding because of visible mutual benefits. These partnerships are often able to ultimately access international funding and facilitated bidirectional transfer of technology (i.e., Africa to the UK, and vice versa).

Research driven by common interests

An important aspect in any successful partnership is a shared passion for a specific research objective or a target organism, in which both partners have a strong interest. The selection of an appropriate target organism may be the first and foremost hurdle to overcome in establishing a strong partnership in Africa. African scientists generally conduct research that is driven by local priorities (i.e., socioeconomic conditions, food shortages, alleviation of poverty, medicinal properties, etc.). Hence, they often focus on a food crop or indigenous species of local importance that has little or no relevance to potential partners in the "North."

Partners must always have proven research expertise and a strong publication record in their respective research fields. In our studies, for example, plant stress biology is a common "interest" (Box 1). Most of Sub Saharan Africa is in the grip of climate change–associated variability in weather patterns with accompanying changes in the spread of pests and diseases (Botha et al., 2020). The focus of our studies on plant stress biology is especially useful in building platforms for scientific cooperation and expanding partnerships. The negative impacts of environmental stress e.g. abiotic stresses, including drought or biotic stresses such as insect pests on crop productivity, is a global problem. Hence, finding funding to support longer-term partnerships is somewhat easier because we address the Sustainable Development Goals of the United Nations. The inclusion of a major crop, such as soybean and wheat, which are of interest to both

Box 1 **Climate change partnership to train African academics and students in plant stress**

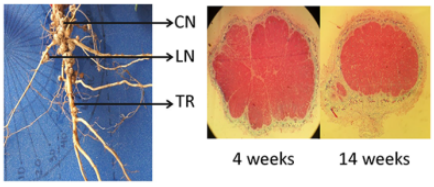

Figure Left: Soybean tap root (TR) with crown nodules (CN) and lateral root nodules (LR). **Middle:** Nodule cross-sections of 4 weeks-old crown nodules containing leghemoglobin and actively fixing nitrogen. **Right**: Nodule cross-sections of 14 weeks-old senescent crown nodules with degraded leghemoglobin and low nitrogen fixation due to exposure of soybean plants to drought conditions.

Figure Left: Mutant wheat lines with enhance water stress tolerance in the field. **Top right:** Aphids caged on Arabidopsis to study plant-aphid interactions; **Bottom right:** Control and mutant wheat lines. Mutant wheat shows better root development.

Nearly a billion Africans are food insecure and suffer from starvation, under- and malnutrition. A key driver in this scenario is Africa's unprecedented and frequent droughts, impacts particularly crop productivity in Southern and Eastern Africa. Effects of water deficit stress in soybean nodules were studied to assess how it contributes to the decrease in crop productively (Quain et al., 2015; Kunert et al., 2016). From the study if was concluded that the direct screening of root and nodule traits in the field as well as identification of genes, proteins and also metabolites involved in such traits will be essential in order to gain a better understanding of the regulation of root architecture, bacteroid development and lifespan in relation to drought tolerance in soybean.

Mutant and transgenic wheat that was developed displayed enhanced water stress tolerance in the greenhouse and field (Le Roux et al., 2019) and plant-aphid interactions studied (Swiegers et al. unpublished).

Benefits of such partnerships include frequent communication and sharing of ideas, easy access to better facilities, availability of study material and access to experimental farms, all contribution to **better quality research outputs**, and **improved visibility**. Students working on such projects get exposed to International experts in the field. Expertise of members within the partnership is multifaceted and from diverse research fields (such as plant physiology, plant breeding, genetics and genomics, bioinformatics). Training of staff and students were facilitated through workshops (such as "Legumes for Life"), short courses, and student exchange.

Hurdles experienced by the partners included **physical geographic distances** making it impossible to meet on a regular basis. The financial implications of meeting regularly. **Funding instruments** usually fund joint projects for one cycle, and then funding must be sought from another funding agencies.

Including multiple African partners **increases the risk on deliverables and outcomes**. Also, more challenging to manage the fund distribution as the funding models differ at the different institutions.

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Europe and Africa, is also important. Lessons learned from the partnership are presented in Box 1.

Significant benefits come through joint projects on important model plants, such as Arabidopsis, tobacco and poplar, in which the consequences of genetic modification can be tested and the effects of specific gene targets characterized. Such activities result in an increased number and quality of research outputs (Kunert et al., 2016; Quain et al., 2015). For example, in total, Professors Kunert and Foyer have published 36 joint peer-reviewed articles in International Journals together. Of these, 25 papers that were published in the last 18 years include other African researchers and their partner countries. Moreover, over the same period a further 7 joint publications were achieved through collaborations between Professor Foyer and other colleagues in Africa. These numbers highlight how successful partnerships can be in achieving significant research outputs.

There is a strong general political and governmental interest in Biotechnology. This was a distinct advantage in finding governmental support for our research activities, because we are able to obtain funding in the form of stipends, scholarships and bursaries, which supported capacity building through staff and student training. In these partnerships two African students undertook the PhD studies through the Commonwealth Split-Site Scholarship Program, and 15 other African researchers undertook joint MSc, PhD or post-doctoral training studies through similar financial instruments. All of these trainees now have good jobs in Academia, agro-industry or Government, mainly in Africa but also in other countries. These facts bear testimony to the benefits of joint training programs offered by the partnerships. Moreover, the associated technologies that were applied in these studies were successfully transferred from Southern Africa to the rest of Africa allowing rapid development in several African partnerships. This partnership also produced improved model and crop plants that have improved tolerance to environmental stresses such as drought and low temperatures (Kunert et al., 2016; Le Roux et al., 2019; Quain et al., 2015). The development and application of the biotechnological tools for plant improvement against environmental stress has become the major focus of many joint funding applications by scientists worldwide in collaboration with African partners.

Hurdles to overcome in the establishment of successful partnerships

Availability of a well-established infrastructure

The absence of well-developed science and technology infrastructure can pose a major challenge to the establishment and maintenance of long-term scientific partnerships in Africa. Only a few African countries (e.g., South Africa), have appropriate science and technology infrastructure with sufficient resources to equip labs and provide scientists with the necessary support to establish successful international scientific partnerships. In general, African scientists are

very poorly funded with much less resources than their fellow scientists in the "North" (Table 1). Although the situation varies from country to country, most African universities and science councils are confounded by poor or outdated infrastructure with inadequate instructional technologies (Saywerr, 2004). International standards for high quality and internationally competitive science can only be achieved in an enabling research environment, where scientists have access to appropriate infrastructure, with an efficient administration and financial support in their respective universities. Unfortunately, there is a lack of experience in many African institutions in the administrative and financial structures required to manage large research projects that include with many partners such as those supported by EU funding instruments.

Lack of well-trained academics

Underperforming and ill-prepared education systems are an additional hurdle for some Africa scientists (UNESCO, 2016). Academic institutions in Africa often have large student numbers and underqualified academic staff (*The Star*, 2019). African scientists can be overwhelmed by teaching duties and the associated paperwork. This allows little time for the research and other activities required to set up successful long-term scientific partnerships. Unfortunately, the drop-out rates of students at tertiary level in many African countries is high, with very few students that enroll for degree programs finishing, and there are few Masters Programs. This means that African academics can have little or no practical training in the laboratory. This trend has dire consequences for the educational system at large, because the number of academics (who undertake the teaching these institutions) who have PhD degrees is low (*The Star*, 2019). A lack of PhD-level training can not only give rise to insecurity but also represent a severe logistical challenge even at planning stages of scientific partnerships. In such cases, it is crucial that goals and expectations are realistic. It is therefore important to recognize and build on the strengths of the African scientists, who can have extensive field experience, knowledge of the agro-ecological systems and cultural practices, as well as crucial local and farm-level networks. The lack of appropriate technical skills can then be addressed through workshops and training courses as part of the partnership and capacity building program. Many funding instruments are available to support of these types of initiatives (e.g. the British Council funded workshops).

African countries are currently investing in the development capacity building to address these urgent educational needs and improve the numbers of PhD graduates in academic institutions by supporting students in studies abroad or through local training initiatives. For example, the research chairs initiatives of the African Institute for Mathematical Sciences (AIMS) (https://www.nexteinstein.org/), the South Africa Research Chairs Initiative (SARChI) and other activities in South Africa (https://www.nrf.ac.za) focus on the establishment of internationally recognized research groups in Africa. These new teams will undertake international competitive cutting edge basic research on topics of interest bearing in mind the need to respond to priorities in Africa, while building and sustaining valuable partnerships within and outside the continent. These programs are designed to minimize the administrative burden on researchers and minimize the teaching loads of incumbents, so that they can dedicate almost all of their time to building research strength. Such initiatives should make a significant contribution to the capabilities and international visibility and competiveness of African science. These programs will, by their very nature, improve the extent, delivery and impact of research capacity, providing the essential underpinning mentorship and networking opportunities for early stage researchers at African universities.

The "North-South" scientific partnerships work best when students are well trained, with experience in well-established and well-resourced laboratories. This not only enables the transfer of skills and technology with the implementation of new transferred know-how, approaches and methodologies that originate within the partnership, but it also builds the confidence of the early stage researchers because they have a portfolio of additional skills such as experience in grant and publication writing, presentations at international meetings, mentoring and networking.

In many African universities there are currently simply not enough senior, qualified faculty staff with PhD degrees, who can provide the necessary mentoring and other support (*The Star*, 2019). Very few African universities offer post-doctoral training, which is again primarily due to a lack of mentorship and funding (Kumwenda et al., 2017). This is further exacerbated by the brain drain from Africa (Mouton, 2018). These contributing factors limit the pool of highly trained students and scientists who are actively engaged in research. Moreover, poor research infrastructure, lack of in-country research funding, and supervisory support often frustrates highly trained early stage researchers returning to Africa, because they do not have the necessary academic environments to apply their skills and knowledge. Resentment can also occur because the junior staff members can be better trained with more international experience than the established academics within the organizations.

Research funding for training, research and development

Any successful scientific partnership needs sufficient funding. A shared passion and involvement in important, interesting and cutting-edge science is not enough to sustain partnerships. As previously discussed (Figures 1 and 3), some of the most important funding instruments that support "North-South" research partnerships include the EU, African Union, the Royal Society and the British Council (UK), as well as the National Research Foundation in South Africa, which makes a significant contribution to bilateral international partnerships between African scientists and other researchers across the world. This also includes scientific partnerships with the UK, through the Newton Fund, and also bilateral partnerships with several African countries (https://www.nrf.ac.za). The CGIAR network is very active in many parts of sub-Saharan Africa. A number of these organizations

such as IITA, ICRISAT, ICRAF, CIP and CIMMYT facilitate "North-South" partnerships supported by funders such as the Bill and Melinda Gates Foundation. Unfortunately, our interactions with CGIARS has been limited, although in the last 20 years one of the South African partners supervised a PhD student from Ethiopia with financial support and co-supervision from CIAT, as well as two PhD students supported by and co-supervised by IITA in Uganda.

The above funding instruments only provide funds to initiate partnerships, but not for sustaining partnerships or follow-up projects. This lack of continuity often has disastrous consequences for the research effort in Africa because the African researcher not only has to drop any potentially interesting line of research to take up another, but also all the progress made in the initial project can be lost or overturned to facilitate the new project that is funded. It is extremely difficult even for well–established researchers to obtain follow-up funding for a longer-term interactions with Africa, and it is almost impossible in the case of early stage scientists, who do not have international research profiles. National funding bodies in Africa are rarely in the financial position to provide further support for the partnerships that have been initiated. In most cases therefore international partnerships and consortia are therefore transient because it is almost impossible to sustain essential financial support.

For sustainability, all partners must be able to access additional national and international funding. In the case described in Box 1, several funding opportunities were accessed, enabling extensive and long term student exchange between South Africa and UK. This exchange not only facilitated the transfer of expertise and technology between the partners, but also tapped into the existing African networks initiated by the South African partner (e.g., Uganda, Ethiopia, Mozambique and Namibia). In this way, we were able to extend the partnership to other early stage scientists across Africa, in a way that supported their career development and professional achievements as well as increasing their understanding of how to prepare grant proposals, manage research projects and present their findings. These are among the many benefits that accrue from a successful scientific partnership.

Overall, having sufficient funding and resources is a must in any successful "North-South" scientific partnership (Sawyerr, 2004). Inadequate research funding, a common problem for African universities, in combination with poor infrastructure and minimal research outcomes will be a stumbling block to any partnership with a scientist from the "North" (Ekundayo and Ajayia, 2009). Moreover, a common problem is that any promised funds to African scientists either arrive late or they receive much smaller amounts than initially promised. This problem restricts the ability of African scientists to operate effectively and efficiently, and thus to contribute effectively in a partnership. The reasons for such funding delays or restrictions is often political leading to low morale, expectations and commitment by staff.

A lack of accountability in the academic administrations can also have a negative impact on "North-South" partnerships. In such circumstances, the partnership can become one-sided and generally unfair to the African partner because the partner in the "North" takes charge of the administration of joint funds. Building trust is essential in such circumstances. Each partner must be allowed to manage their own funds, facilitate accurate accounting and ensure that the funds are used appropriately. The requirement to submit requests for payments unbalances the partnership, not least because it places too much emphasis on the superiority of the infrastructures of the non-African partner in the "North." The equitability of funding is an important step to capacity building, through the acquisition of essential skills in project management and accountability by the African partners, who then can move toward leading partnerships and consortia.

Joint publications and grant writing

African scientists often lack internationally-competitive publication records and have relatively little experience in writing grants or manuscripts for publication. This lack of experience can create problems in partnerships, prevent access competitive research funding and limit technology transfer, limiting capacity building. Strong and successful long-term sustainable scientific partnerships are not built on inequality. Ideally, therefore partners should have a proven publication record before engaging in a scientific partnerships. However, it is difficult to achieve a completive publication record in a poor research environment. Hence, very few African scientists publish in higher impact scientific journals (Figure 1). One exception is South Africa, which is therefore currently comparatively stronger in science and technology than many other countries in Africa (Patra and Muchie, 2019).

Hence, the scientists in the "North" should help the researchers in the "South" to access networks and institutional connections that promote visibility. Joint publications, particularly where the African partner is the first or last author, can provide a springboard to networking, because they result in invitations to workshops and international meetings/conferences as presenters or even session Chairs or facilitators. A key objective of any partnership should be to support the establishment of African researchers within the global research community and enable the less advanced institutions to build complimentary skills, through courses and in-house training.

Appreciation of cultural and social differences

Finally, one should not underestimate the impact of cultural differences and drivers in partnerships with Africa. Universities are diverse spaces with students of different races, indigenous peoples, language groups, cultural backgrounds and practices, and diverse socioeconomic backgrounds. Cultural differences can exert effects on a wide range of issues such as responses to environmental problems and the logic derived from indigenous knowledge (Thondhlana and Shackleton, 2015). Gender issues should also be considered in partnerships. A recent World Bank Group report (Wodon and de la Brière, 2018) revealed that global wealth would increase by $23,620 per person, on average, if women were allowed to contribute equally to household incomes. This is

a key issue because women are still less likely to graduate from tertiary institutions or participate in the academic workforce of many African countries (UNESCO, 2017).

Specific pilot areas (PAs) were studied in a human capacity building project that was designed to stimulate economic growth and social development, and to alleviate poverty in six African countries (Box 2). The country-specific pilot areas (PAs) promoted cooperation, knowledge transfer, capacity building, trust and partnerships in regional applied research groups, their local communities and related water management institutions with the participation of NGOs. This project approach encouraged local ownership with useful outcomes at each PA, while strengthening the links between countries, local and regional networks and international counterparts. There were significant outcomes in three focus areas: water for livelihood, water for agriculture, and social and economic dimensions of water resources management. In this way, the communities within the targeted areas in Africa achieved higher standards of wellbeing through a range of opportunities to reduce poverty and improve livelihoods. The lessons learned from this study are presented in Box 2. The scientists participating in this project were well-trained and chosen for their expertise within the field but they faced the challenges arising from a lack of institutional capacity that delayed funding and consequently the progress of the study.

Box 2 **Lessons learnt from a partnership to train African Scientists in Integrated water resource management (IWRM)**

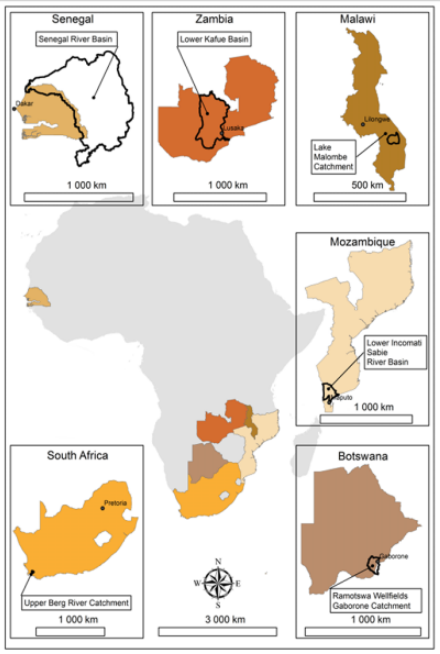

Figure The IWRM pilot study areas for the project partners from Botswana, Malawi, Mozambique, Senegal, South Africa and Zambia.

IWRM practices was employed in pilot areas in six African countries. Project management and research progress in the project were hampered by several hurdles.

Obstacles in **project management** included legalities and finalizing of contracts between the partners which took extremely long; transfer, administration and auditing of funds were difficult; delayed project reporting and slow responses made feedback to funding bodies difficult; language barriers, poor IT and other infrastructural constraints hampered communication; and fast turnover of staff components posed challenges to project continuity.

Difficulties experience in the **research progress** included for example, the IWRM processes at each pilot area were influenced by unique political, social economic and culture conditions. Which then showed that it is imperative to follow a bottom-up approached, having community and stakeholders identify water quality challenges, linking social and economic development to support that best IWRM practices that can be successfully implemented in African countries. For all the target groups, the main constraints in the study related to: (a) lack of adequate numbers of staff at all levels of experience, (b) the failure to knowing of and considering existing best practice options, (c) inadequate financing to evaluate feasible alternatives, and (d) then not being able to take the right steps to resolve the communities' identified issues and challenges with sustainable solutions. It was further evident from the study that transdisciplinary research within academic institutions was a major obstacle with little interaction between social and environmental scientists.

Lessons learned To overcome these obstacles it is advisable to follow a bottom-up transdisciplinary research approach which include all academic institutions and science councils, community leaders and other stakeholders with the onset of any project. Lessons learned form this experience can be valuable in the establishment and management of long-term collaborations with African countries.

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Conclusions and recommendations

Like science, successful partnerships must be receptive to solving the global challenges that society prioritizes. Similarly, successful partnerships are founded in human interactions and priorities. We have used our experience in facilitating long term partnerships to highlight the many benefits and pitfalls of such scientific relationships. We consider that the bedrock of any lasting scientific partnership is trust, as well as flexibly, a willingness to invest time, money and information. All partners should be equal in these respects. The willingness to actively invest time into the partnership is often determined by the level of mutual interest in the research topic. The successful completion of a joint research activity is rewarding but the outcomes can be transient particularly if the partnership is not sustained. Funding in Africa comes in bursts, arriving from agencies with different drivers and priorities. The arrival of new funding can result in activities that totally undo the achievements of the previous project. Hence, long-term scientific partnerships are crucial to the effective translation of research outputs into society. Sustainability can only be achieved, if the partners are supported by effective and efficient institutional structures. It is thus recommended that all new funding initiatives provide training of financial support staff in project management. Many African scientists currently have to manage the administration of finances, instead of focusing solely on the science. Such messages resonate with policy-makers and

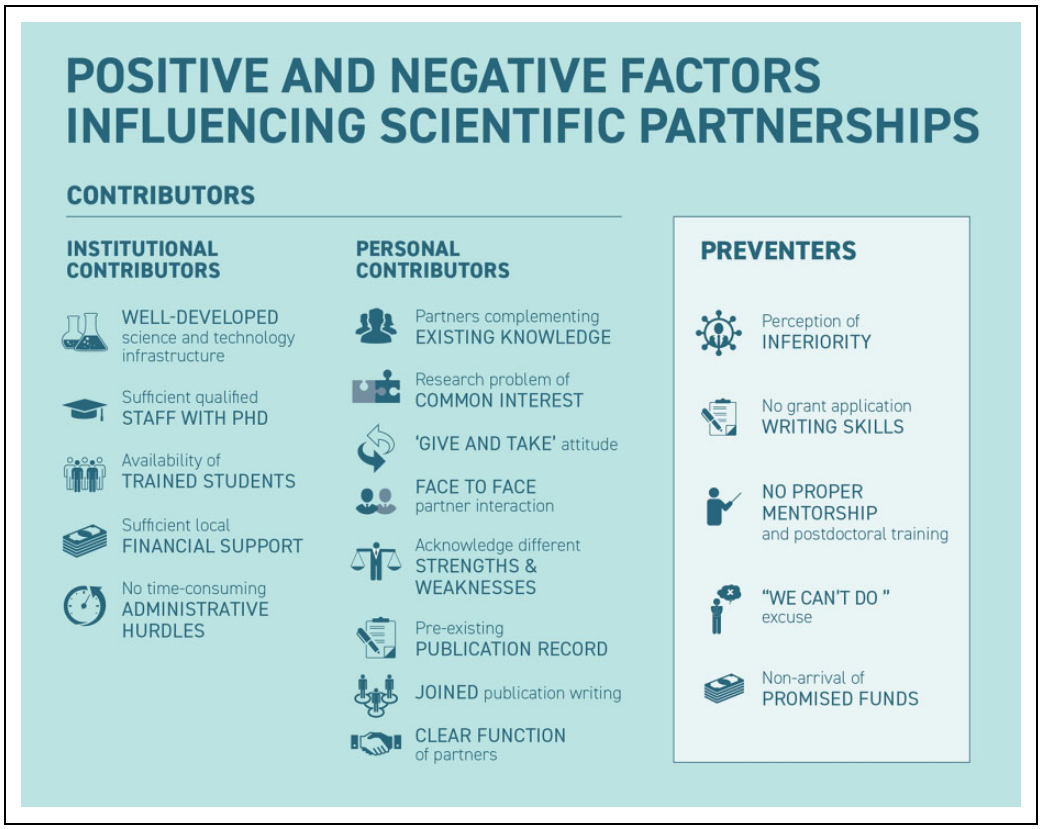

Figure 4. Positive and Negative factors influencing scientific partnerships.

investors after decades of declining investment in areas such as agriculture and food security research.

Consideration must be given to the establishment of enabling institutional environments with well-developed administrative, legal and financial support systems, good governance and clear policies, that is supported by strong leadership to ensure sustained, long-term partnerships with African Scientists. Figure 4 summarizes some of the important contributing factors and hurdles that were found to be important in our partnerships, and through the two case studies presented here. Successful "North-South" scientific partnerships within Africa, and between African scientists and those from developed countries (such as the UK) will be increasingly important in knowledge generation, as well as the establishment of world leading R&D in African institutions. Relevant research networks that advance global research agendas, for example in agriculture, are important priorities for governments in both the "North" and the "South." We consider that joint activities will enable African science to find its true place in being a global science, initiating and driving completely new fields of endeavor and research. Sustainability requires long-term commitment and funding on a global scale. We consider that Africa has the potential not only to produce enough food for its own population (Foyer et al., 2019) but also to make a significant contribution to global food security. If justice and fairness prevail, long-term scientific partnerships will be successful and be a key driver in the success of African science.

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References

Adams J and Loach T (2015) Comment: a well-connected world. *Nature* 527: S58–S59.

African Union (2015) African Union Research Grant Programme: Promoting Science and Technology for Sustainable Development of Africa. Available at: https://au.int/sites/default/files/newsevents/workingdocuments/27671-wd-23_-_aurg-booklet-draft-v3_0.pdf (accessed 26 April 2020).

Bailey-Serres J, Parker JE, Ainsworth EA, et al. (2019) Genetic strategies for improving crop yields. *Nature* 575: 109–118.

Blagescu M and Young J (2005) *Partnerships and Accountability: Current Thinking and Approaches Among Agencies Supporting Civil Society Organizations*. London: ODI.

Bradley M (2008) *On the Agenda: North-South Research Partnerships and Agenda-Setting Processes*. Ottawa: IDRC.

Botha A-M, Kunert KJ, Malinga JM, et al. (2020) Defining biotechnological solutions for insect control in sub-Saharan Africa. *Food Energy and Security* 9: e191.

Carbonnier G and Kontinen T (2014) North-South Research Partnership: Academia Meets Development? EADI Policy Paper Series, Bonn.

Ekundayo HT and Ajayia IA (2009) *International NGO Journal* 4(8): 342–347. August, 2009. Available at: http://www.academicjournals.org/INGOJ (accessed February 2020).

Foyer CH, Siddique KHM, Tai APK, et al. (2019) Modelling predicts that soybean is poised to dominate crop production across Africa. *Plant Cell Environment* 42: 373–385.

Kumwenda S, Niang EHA, Orondo PW, et al. (2017) Challenges facing young African scientists in their research careers: a qualitative exploratory study. *Malawi Medical Journal* 29: 1–4.

Kunert KJ, Vorster BJ, Fenta BA, et al. (2016) Drought stress responses in soybean roots and nodules. *Frontiers in Plant Science* 7: 1015.

Langer A, Diaz-Olavarrieta C, Berdichevsky K, et al. (2004) Why is research from developing countries underrepresented in international health literature, and what can be done about it? *Bull World Health Organ* 82: 802–803.

Le Roux ML, van der Vyver C, Kunert KJ, et al. (2019) Expression of a small ubiquitin-like modifier protease increases drought tolerance in wheat (*Triticum aestivum* L.). *Frontiers in Plant Science* 10: 266.

Leydesdorff L, Wagner C, Park HW, et al. (2013) International Collaboration in Science: The Global Map and the Network. Available at: https://arxiv.org/ftp/arxiv/papers/1301/1301.0801.pdf (accessed February 2020).

Mouton J and Blanckenberg J (2018) African science: a bibliometric analysis. In: Beaudry C, Mouton J and Prozesky H. (eds) *The Next Generation of Scientists in Africa*. African Minds, Somerset West, SA; Oxford, UK. pp. 13–25. ISBN Paper 978-1-928331-93-3. Availabel at: http://www.africanminds.co.za/wp-content/uploads/2018/10/AM-The-Next-Generation-of-Scientists-in-Africa-TEXT-WEB-11112018-1.pdf (accessed 7 April 2020).

Mouton J (2018) African Science: a diagnosis. In: Beaudry C, Mouton J and Prozesky H. (eds) *The Next Generation of Scientists in Africa*. African Minds, Somerset West, SA; Oxford, UK. pp. 3–8. ISBN Paper 978-1-928331-93-3. Available at: http://www.africanminds.co.za/wp-content/uploads/2018/10/AM-The-Next-Generation-of-Scientists-in-Africa-TEXT-WEB-11112018-1.pdf (accessed 7 April 2020).

Nyaundi L and Kimani T (2019) Varsities face staff crises as half of PhD students quit. *The Star*, 21 March. Available at: https://www.the-star.co.ke/news/2019-03-21-varsities-face-staff-crises-as-half-of-phd-students-quit/ (accessed 22 April 2020).

Omungo R (2018) Africa's science "millionaires": survey spotlights top-funded researchers. *Nature online*. Available at: https://www.nature.com/articles/d41586-018-07418-6NatureISSN1476-4687(online) (accessed 8 April 2020).

Patra SK and Muchie M (2019) What patents and publications reveal about China-Africa science collaboration. *The Conversation, 29 August*. Available at: https://theconversation.com/what-patents-and-publications-reveal-about-china-africa-science-collaboration-122429 (accessed 8 April 2020).

Quain MD, Makgopa ME, Cooper JW, et al. (2015) Ectopic phytocystatin expression increases nodule numbers and influences the responses of soybean (*Glycine max*) to nitrogen deficiency. *Phytochemistry* 112: 179–187.

Sawyerr A (2004) African Universities and the challenge of research capacity development. *Journal of Higher Education in Africa / Revue de l'enseignement supérieur en Afrique* 2(1): 213–242. Special Issue: African Higher Education: Implications for Development (2004).

Thondhlana G and Shackleton S (2015) Cultural values of natural resources among the San people neighbouring Kgalagadi Transfrontier Park, South Africa. *Local Environment* 20: 18–33.

UNESCO (2016) School resources and learning environment. Available at: uis.unesco.org/sites/default/files/school-resources-and-learning-environment-in-africa-2016-en/school-resources-and-learning-environment-in-africa-2016-en.pdf.

UNESCO (2017) Women in science. UNESCO Institute of Statistics Fact Sheet No. 43, March 2017. FS/2017/SCI/43. Available at: http://uis.unesco.org/sites/default/files/documents/fs43-women-in-science-2017-en.pdf (accessed 10 April 2020).

Wodon QT and de la Brière B (2018) *Unrealized Potential: The High Cost of Gender Inequality in Earnings. The Cost of Gender Inequality*. Washington, DC: World Bank. © World Bank. °Available at: https://openknowledge.worldbank.org/handle/10986/29865License:CCBY3.0IGO (accessed 10 April 2020).