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Sustainable Statistical Capacity-Building for Africa: The Biostatistics Case

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Abstract

Several major global challenges, including climate change and water scarcity, warrant a scientific approach to generating solutions. Developing high quality and robust capacity in (bio)statistics is key to ensuring sound scientific solutions to these challenges, so collaboration between academic and research institutes should be high on university agendas. To strengthen capacity in the developing world, South–North partnerships should be a priority. The ideas and examples of statistical capacity-building presented in this article are the result of several monthly online discussions between a mixed

group of authors having international experience and formal links with Hasselt University in Belgium. The discussion focuses on statistical capacity-building through education (teaching), research, and societal impact. We have adopted an example-based approach, and in view of the background of the authors, the examples refer mainly to biostatistical capacity-building. Although many universities worldwide have already initiated university collaborations for development, we hope and believe that our ideas and concrete examples can serve as inspiration to further strengthen South–North partnerships on statistical capacity-building.

1. INTRODUCTION

1.1. The Need for Statistical Capacity

The Addis Ababa Action Agenda on financing for development, the United Nations (UN) Sustainable Development Summit in New York, and the Paris Agreement on climate change rendered the year 2015 a landmark in shaping global policy. A fundamental idea is that grand challenges such as enabling good health, good education, climate action, and clean water require a joint approach and hence collaboration at a global scale. Networks tackling these challenges should consist of nodes of excellence that possess appropriate scientific capacity. For most if not all such challenges, data science and statistical capacity are indispensable to providing sound advice for decision and policy makers, and this partly explains the increasing demand worldwide for statisticians and data scientists. In addition, it shows the urgency of having well-trained statisticians at the many nodes in the network; in other words, local statistical capacity (in-country capacity) is needed, capitalizing on South–North and South–South collaborative efforts.

The UN General Assembly underlined this need by declaring 2022 the International Year of Basic Sciences for Sustainable Development (**https://www.iybssd2022.org/en/about-us**). The further development of statistical capacity on a global scale can doubtless contribute to this ambition.

Networking is broadly beneficial for capacity-building and is crucial in an African context—first, because there is a critical skills shortage. The current population of Africa is estimated to be 1.2 billion and is expected to double in the next 30 years. The African continent, however, has only 198 researchers per million population, in contrast to Europe and the United Kingdom, which have more than 4,500 researchers per million population (Kariuki & Kay 2017). Kasprowicz et al. (2020) attribute this to several challenges: The shortage of well-trained and skilled researchers results in poor supervision of postgraduate students; there are weak or limited career progression ladders for those in scientific careers; the research infrastructure is poor; and research support services are often inadequate. As such, concentration of mentorship and capacity-building in Africa is key to providing research leadership. Furthermore, there is a need to support fellows beyond PhD training to ensure that they grow into leaders. Second, there has been an increased need for research in the Global South, hereafter referred to as the South, due to an increased disease burden. For example, a World Health Organization (WHO) report (WHO 2021) shows that African countries are at the top of the list of high-burden countries for tuberculosis and HIV-associated tuberculosis, and Roser & Ritchie (2021) show higher mortality and morbidity in Africa relative to other regions. This burden has to be matched with an increase in researchers to provide for interventions. Specifically, for biostatistics, research studies related to high disease burden have generated valuable regional data, which have not been optimally analyzed due to limited statistical capacity. A third challenge in biostatistics is historical disadvantage: While countries in Europe and the United States have long offered master's degrees, postgraduate training in biostatistics has only recently appeared on the African agenda.

1.2. Statistics and Data Science

Evidence-based action in medicine, management, or policy should be based on data supporting an assumed hypothesis and on methods that let the data speak. This is where statistics comes in: Time series analysis should be used to underpin policy on deforestation, and statistical models should help to determine the main factors driving climate change or to improve patient outcomes, for example.

Data are key, and the amount of available data is enormous (Beyene et al. 2020). Data are the raw material, and statistical methodology provides tools to shape them and synthesize their information. Increased computer power and storage have boosted artificial intelligence and machine learning, especially in the context of big data, but these computational methods also have an important statistical dimension. The "big data train" will move fast if it can rely on the "energy" from statistical capacity.

1.3. Our Approach to Statistical Capacity-Building

Statistical capacity-building (in the South) is a theme to which many conferences, projects, and papers have been devoted, and many ideas have been proposed (Gezmu et al. 2011, Chirwa et al. 2020, Carpenter et al. 2022) based on well-documented needs.

To reflect on statistical capacity-building, we formed a small group of (bio)statisticians (the coauthors of this article). Each African coauthor has a link with Hasselt University (UHasselt) in Belgium as a former master's degree and/or PhD student, as a lecturer, or as an advisor. All African coauthors returned to Africa after their studies, perform in-country dissemination of statistics in academia or in research institutes, and have both local and international experience. The three Belgian coauthors teach or taught in the master of statistics (and data science) program at UHasselt and have substantial extended experience in South–North university cooperation. The countries represented by the African coauthors are Ethiopia (Tadesse), Kenya (Mwangi), Malawi (Chirwa), South Africa (Reddy, Chirwa), and Uganda (Nsubuga), though the experience gained and to be shared here cuts across countries in eastern and southern Africa (**Figure 1**), the region on which we focus in this article.

In a number of online meetings, we had open conversations starting from two simple questions: (*a*) In view of the three basic tasks of a university, education (Section 2), research (Section 3), and service to society (Section 4), what is the level of statistical capacity in your country? (*b*) In relation to statistical capacity-building, what good practices and challenges (at the university, country, and international levels) exist?

Given the characteristics of our group (all work in biostatistics), we do not cover statistical capacity-building at large in this article but aim to compile practical ideas on this activity in the South and to demonstrate and exemplify some of them. We strongly believe that overarching collaboration (South–South or South–North) is key to capacity-building and that such collaborations are a win-win for all participating parties who hope to contribute to solutions of global challenges. This agrees with the conclusions of Gezmu et al. (2011), who discuss collaboration through US partnerships, and Carpenter et al. (2022), who describe the impact of the London School of Hygiene and Tropical Medicine on (statistical) capacity-building.

VLIR-UOS (Vlaamse Interuniversitaire Raad Universitaire Ontwikkelingssamenwerking, the Higher Education Cooperation for Development section within the Flemish Interuniversity Council) offers opportunities for South–North and South–South collaboration, and in Appendix A we detail its role as a university cooperation for development, policy makers, and funding agents in the Flemish region of Belgium. A list of abbreviations used in this article is given in **Table 1**.

Figure 1

The countries represented by the African coauthors (*red*): Ethiopia, Kenya, Malawi, Uganda, and South Africa.

2. STATISTICAL CAPACITY-BUILDING THROUGH EDUCATION

2.1. The Four Themes in Education Development

Establishing, developing, and maintaining education programs in statistics in the South are fundamental to ensuring a high level of statistical capacity there. While the establishment of new undergraduate, graduate, and PhD programs in the South is critical, we must also continuously update existing programs and maintain their quality, as the level will otherwise progressively decline. These ambitions require actions in four different areas:

1. Curricula:
   - A minimum curriculum for training biostatisticians at the master of science (MSc) and PhD levels is needed. We recommend that curricula be accredited by a national or international committee.

Table 1 Common abbreviations related to statistical capacity-building in Africa

Abbreviation	Definition
DELTAS	Developing Excellence in Leadership, Training and Science in Africa Scheme
IBS	International Biometric Society
IBS-SUSAN	International Biometric Society Sub-Saharan Network
ICP	International Course Program (a VLIR-UOS program)
ISI	International Statistical Institute
IUC	Institutional University Cooperation (a VLIR-UOS program)
NASCERE	Network for Advancement of Sustainable Capacity in Education and Research in Ethiopia
NIH	National Institutes of Health
SACEMA	South African Centre of Excellence in Epidemiological Modelling and Analysis
SAMRC	South African Medical Research Council
SIDA	Swedish International Development Cooperation Agency
SSACAB	Sub-Saharan African Consortium on Advanced Biostatistics Training
SUSAN	Sub-Saharan Network (of the IBS)
UHasselt	Hasselt University (Belgium)
VLIR	Flemish Interuniversity Council
VLIR-UOS	Higher Education Cooperation for Development section within the Flemish Interuniversity Council
WITS	University of the Witwatersrand (South Africa)

- The curriculum should have a good balance between methodological and applied components.
- Within-country networks with research institutes should be created to facilitate the practical training of students.

2. Human capital:
   - Development of high-quality course material to ensure that the training of the graduates is on par with that in the North is required, as often junior academic staff members (typically MSc graduates) teach MSc courses due to a shortage of PhD graduates.
   - In the long run, the number of staff holding a PhD should increase. Hence, an increase in joint PhD projects and the development of local doctoral schools are essential.
3. Digital education:
   - Electronic learning (e-learning) systems should be propagated.
   - Staff should be trained to be familiar with the use of e-learning systems.
   - Core courses that are available online should be listed and fully developed so that they are ready to be used by teachers and students.
   - Distance learning programs should be used to build a solid curriculum but should not entirely replace the education program in the South.
4. National and international collaboration:
   - South–North and South–South collaboration can and should be instrumental for both course development and maintenance.
   - Accessibility should be guaranteed by sharing the material in a repository specifically set up for training.

The above curriculum recommendations were made to address problems related to existing bachelor's degree and graduate education programs. At the bachelor level, many education

programs in statistics are focused on classical statistical theory, with little emphasis on applications, so students have a good theoretical background but minimal exposure to data analysis in disciplines such as epidemiology, clinical studies, public health, and medical statistics. The resulting lack of applied knowledge might even mean that students in statistics miss its key role in the biosciences. Furthermore, modern methods such as machine learning, big data analytics, advanced statistical computing, and data science methods are not yet part of most curricula. At the master level, some programs are mainly thesis-oriented and lack curriculum courses. Even those programs that offer courses may struggle to incorporate modern data analysis techniques and innovation into the curriculum.

To overcome these problems, networking with within-country research institutes might provide a good way to reinforce the applied component that is needed in biostatistical programs to ensure that applied statisticians with balanced theoretical and applied skills can take up their indispensable role in biosciences. This will create forums for interaction between research institutes, universities, and trainees; provide required research experience and exposure; and demonstrate the role of (bio)statistics in reaching sound scientific conclusions.

The human capital recommendations were based on a major and common problem faced by many African universities, namely the shortage of PhD holders. Currently, it is mostly MSc graduates who develop, teach, and maintain MSc courses. A short-term solution is to ensure that the quality of the course material is high. In the long term, efforts should be undertaken to increase the number of staff holding a PhD and having the opportunity to continue research once they are in academia, and to establish training programs for junior and inexperienced academic staff.

The digital education recommendations were formulated to address the main problems related to curriculum development and maintenance, and the challenge posed by the COVID-19 outbreak, which forced many universities to switch to online teaching and distance learning modules. Some were already equipped with e-learning environments, such as Moodle or Blackboard, but the use of these platforms increased substantially. Some key benefits of digital education, such as the ability to reach a larger group of students and the flexibility of having teachers from other universities and countries in the program with minimal expenditure or additional funding, became apparent.

The transition from in-person to online teaching was not always simple, and in some situations, many months were lost before it occurred. Even then, online teaching was not guaranteed because some students lacked computers and access to stable Internet and mobile data. At the same time, universities were often challenged by the lack of faculty uptake of e-learning. To tackle this, university management often increased the support provided to familiarize faculty with the technicalities of e-learning environments. The development of accessible e-learning/digital learning systems can help new educational programs or those running in low-capacity environments to develop high-level curricula relatively quickly. The use of online courses maintained by a course developer can be a short-term solution to the maintenance problem mentioned above.

The national and international collaboration recommendations were formulated because the goal of providing a high-level sustainable education has not yet been achieved and is unlikely to be attained without a strong and continuous collaborative effort of academic institutes from South and North. This will lead to development of educational materials and tailor-made biostatistical curricula at both bachelor and MSc levels, and will improve the within-country human capital by training PhD students under joint South–North and South–South supervision and in collaboration with (medical) research institutes (providing an example of the societal impact of statistics). It will create networks of institutes and people for cosupervision and

hosting students from the South. As a concrete example, Example 2 (Section 2.2.2) describes the impact of the Sub-Saharan Africa Consortium for Advanced Biostatistics Training (SSACAB) (**https://ssacab.lshtm.ac.uk**), which promotes education and research in biostatistics at the MSc and PhD levels. The role of IBS-SUSAN (International Biometric Society Sub-Saharan Network), a network of sub-Saharan biometric groups that are members of the International Biometric Society (**www.biometricsociety.org/about/regions-networks**), as a capacity-building facilitator is demonstrated in Examples 12 (Section 3.5.2) and 17 (Section 4.4.1).

2.2. Examples of Education Development

We now give four examples to illustrate how the ideas on education development, discussed in Section 2.1, can be made concrete.

2.2.1. Example 1: International Course Program at Hasselt University (curriculum development, human capital, international collaboration). In 1988, UHasselt started a master's degree program in biostatistics (in the meantime, the program has been diversified; for detailed information, see **https://www.uhasselt.be/master-of-statistics-and-data-science**), at that time unique in Belgium. Since the 2017–2018 academic year, this program has run on campus but also as a distance learning program. The distance learning program can be followed full-time or part-time, allowing a flexible combination of work and study. It is identical to the on-campus program, with differentiation in assignments where needed for practical reasons, and it is possible to switch between the programs. The current version of the 1988 program is the master of statistics and data science, which now has the four following pillars:

- biostatistics,
- bioinformatics,
- quantitative epidemiology, and
- data science.

Soon after its launch in 1988, many applications were received from students in the South, and a lack of scholarships for such students was the main hurdle to enriching the student population. The 1993 recognition of the program as a VLIR-UOS International Course Program (ICP) (see Appendix A) was the breakthrough to opening it to students from the South.

VLIR-UOS currently provides 10 2-year grants for southern students to pursue the master's degree in statistics and data science. Several courses in the program focus on specific needs in developing countries and are taught together with our partners in the South, such as Capita Selecta of Computational Biology (Samuel Mwalili/Samuel Manda), Design of Agricultural Experiments (Rebecca Nsubuga/Clarice Démetrio), and Infectious Diseases in Low and Middle Income Countries (Khangelani Zuma). The master's degree program offers a solid and balanced mix of up-to-date methodological and applied courses, such as linear and generalized linear models, Bayesian modeling and multivariate models, clinical trials, public health, longitudinal data, survival analysis, high-dimensional data, genetics, and survey methodology. There is a strong focus on applications in modern statistical software packages, such as R, SAS, and WinBUGS. Information on the number of students from VLIR-UOS scholarship countries (see Appendix A for the VLIR-UOS country list) who obtained a master's degree is given in **Table 2**.

For scholarship students from the South, the ICP program provides an international experience of on-campus studies at UHasselt and is often an occasion to build networks for the future. However, for students without scholarships, the expense of studying in Belgium presents a hurdle, so it is crucial to have a distance learning version of the program.

Table 2 Number of students from the VLIR-UOS scholarship countries (with number of African students in parentheses) obtaining an advanced degree in statistics or data science in 2016–2021

Degree	2016–2017	2017–2018	2018–2019	2019–2020	2020–2021
Bioinformatics (MSc)	NA	0	2 (0)	3 (2)	2 (2)
Bioinformatics DL (MSc)	NA	0	0	1 (1)	0
Biostatistics (MSc)	19 (16)	18 (17)	16 (15)	13 (11)	16 (12)
Biostatistics DL (MSc)	NA	0	1 (1)	0	0
Quantitative epidemiology (MSc)	6 (6)	5 (5)	1 (1)	4 (3)	4 (2)
Quantitative epidemiology DL (MSc)	NA	0	0	0	0
Statistics (PhD)	2 (2)	7 (6)	0 (0)	1 (0)	3 (2)

For the titles of the PhDs of the African PhD students, see the sidebar titled African Students' PhD Topics at Hasselt University (2016–2022).
Abbreviations: DL, distance learning; MSc, master of science; NA, course was not available in the specified time frame; VLIR-UOS, Higher Education Cooperation for Development section within the Flemish Interuniversity Council.

2.2.2. Example 2: Sub-Saharan Africa Consortium for Advanced Biostatistics Training (curriculum development, human capital, international collaboration). Statisticians from sub-Saharan Africa trained over time have led to a pool of expertise there, although it is still insufficient in a region bearing the highest global burden of communicable and noncommunicable diseases. Individuals capable of robust, innovative, and elaborate analyses are often overwhelmed, and there is limited capacity to manage and use existing data to inform policy makers and local health service providers. To discuss how to build or enhance existing local capacity, a meeting of biostatisticians was organized in Gaborone, Botswana (Gezmu et al. 2011), followed by another in South Africa (Machekano et al. 2015) funded by the US National Institutes of Health (NIH). The outcome was the formation of SSACAB, founded in 2015, whose goal is to pool the limited biostatistics resources in the region in order to provide training at academic institutes in the South,

AFRICAN STUDENTS' PhD TOPICS AT HASSELT UNIVERSITY (2016–2022)

In the period 2016–2022, 11 African students obtained a PhD at Hasselt University. Below is the list of PhD topics, with each student's country of origin in parentheses:

- Flexible statistical models with applications in reproductive health (Mozambique).
- Prediction of time to threshold from a repeatedly measured biomarker (South Africa).
- Optimization of statistical procedures to assess the diagnostic accuracy of cervical cancer screening test (Kenya).
- Statistical and mathematical methods to improve models of infectious disease transmission in and between human and animal populations (Ethiopia).
- Modeling HIV/AIDS and visceral leishmaniasis treatment outcomes in Ethiopia (Ethiopia).
- Estimating infectious disease parameters for the transmission of malaria in Ugandan children (Uganda).
- Quantile regression in heteroscedastic varying coefficient models: testing and variable selection (Ethiopia).
- Statistical methods for transcriptomic and metabolomic data analysis (South Africa).
- Statistical perspectives on the analysis of disease outbreak data using mechanistic and phenomenological models (Zimbabwe).
- Spatial-temporal models for Ebola and HIV in western and southern Africa (Mozambique).
- Analysis of infectious disease data in Ethiopia: a flexible Bayesian statistical modeling approach (Ethiopia).

with support from northern partner institutes. The consortium is unique in bringing together African and northern academic/research institutes and creating much-needed predominantly South–South collaboration with an international dimension (Chirwa et al. 2020). The SSACAB program constitutes 11 African universities in 11 countries, 4 research institutes, and 4 northern partners and is led by the School of Public Health, University of the Witwatersrand (WITS) (South Africa). Since 2015, SSACAB has been supported by the Developing Excellence in Leadership, Training and Science in Africa Scheme (DELTAS) Africa initiative, funded through the Wellcome Trust. The initial phase aimed at building a critical mass of master's degree and PhD biostatisticians to nurture researchers with advanced skills and expertise. Although the second phase of SSACAB is not yet funded, the consortium hopes to develop nodes of biostatistical excellence, including in machine learning and data science. Since its establishment, SSACAB has developed capacity and supported research and has become an example of an overarching educational network (with universities in the South taking the lead, supported by those in the North). As of 2021, fellowships have been awarded to 130 master's students, of whom several have subsequently been enrolled into the PhD program. These master's and PhD fellows have published their research in high-impact peer-reviewed journals—an achievement that was previously unthinkable. Although SSACAB had initially planned 15 PhD fellowships, a total of 27 (10 female) PhD students have been supported. SSACAB has also provided partial support for PhD students enrolled in partner institutes; staff members; and students of the consortium, the IBS-SUSAN conferences, and the South African Statistical Association. The consortium has also excelled in support for curriculum development to ensure quality and standardization of courses. SSACAB initiated institutional reviews or visits to evaluate the quality of ongoing programs, and adjustments were suggested and implemented for courses found to be below expected minimum standards. In 2015, only 4 universities (out of the 11 partners) had established master's degree programs in biostatistics, and SSACAB supported an additional 5 to develop master's programs and start implementation. In 2019, WITS became the first African institute to gain Royal Statistical Society accreditation for a biostatistics master's program, with other academic institutes to follow. The collection of relevant data for accreditation is ongoing. International collaboration has been key to the success of the SSACAB consortium, with technical advice, PhD cosupervision, and sharing of teaching materials, including physical teaching at institutes in the South from UHasselt, Utrecht University (the Netherlands), and the London School of Hygiene and Tropical Medicine. Within the southern institutes, there are South–South cross-teaching and cross-supervision activities. For example, staff from WITS teach at the University of Namibia, and staff from the University of KwaZulu-Natal teach at the Kilimanjaro Christian Medical University College in Tanzania and the University of Namibia.

2.2.3. Example 3: electronic learning environments and digital education. Over the past 10–15 years, the rapid development of technology, such as bioinformatics platforms in medical research and the capacity to collect and store (typically big) data sets, has led to a constant need to develop new methods of data analysis and to write software in which the new methods are implemented. The scientific community has answered this need by developing many online software tools. Websites such as CRAN and Bioconductor offer thousands of R packages for data analysis, for example. The difference in training facilities for using existing materials has led to a growing gap between northern and southern institutes. The question is not, for example, whether a linear mixed model can be fitted to hierarchical data, but rather where to find the software and how to use it. Both require the data analyst to be familiar with mixed model theory, so accessible training courses are essential.

In a way, this gap represents a paradox. In a world that freely offers advanced and updated tools online for data analysis, the southern scientific community underuses these tools. One solution for this paradox could be the development of training and accessible online programs in statistics via a platform available for both academic staff and students in the South, and from which training materials can be downloaded and used. Two examples of this approach are the OpenIntro and eR-BioStat initiatives. The first is an initiative (**https://www.openintro.org**) to develop educational products that are free, are transparent, and have lower barriers to adoption. It offers online and free books in elementary statistics and supporting resources, such as slides, tutorials, and videos. OpenIntro Statistics is a dynamic take on the traditional curriculum that is successfully used from community colleges to the Ivy League. The eR-BioStat platform (**https://erbiostat.wixsite.com/erbiostat**) is a part of the open-source movement that offers free online courses in statistics. It was developed for teachers who need to give courses in statistics and for students who study statistics. It offers (mostly R-based) materials for data analysis in higher education programs at undergraduate and master in biostatistics/statistics/data science levels and at all levels (including PhD) for nonstatisticians. Both OpenIntro and eR-BioStat follow an open-source approach: The source files used to develop the book/courses can be used by teachers in the South to develop or tailor a course based on the needs of their local program.

2.2.4. Example 4: capacity enhancement through joint projects. International collaboration is key to ensuring continuous educational development. Joint projects that link academic institutes from the South and the North can lead to sustainable education programs in statistics. For example, the long-term collaboration between Moi University (Kenya) and Brown University (United States) for biostatistics training in HIV provides solid biostatistics training and collaboration, benefiting students and faculty at Moi and enhancing HIV research capacity in Kenya (Brown Univ. 2021). This collaboration led to a review of the master in biostatistics curriculum at Moi University. The Johns Hopkins University Program for International Education in Gynecology and Obstetrics (JHPIEGO) has also been instrumental in shaping the medical curriculum, including biostatistics, at the University of Gondar (Ethiopia). The master's and PhD programs at the Department of Epidemiology and Biostatistics at the University of Gondar were established in close collaboration with UHasselt.

A large long-term (2006–2016) Institutional University Cooperation (IUC) program (see Appendix A, Section A.1) between Jimma University (Ethiopia) and the Flemish universities enriched the academic capacity of the research groups involved. In several subprojects, expertise has been developed on the central theme of investigating the impact of the Gilgel Gibe dam: A multidisciplinary approach was taken to investigate the effects of a hydroelectric dam from all possible angles, including human and animal health, ecology, soil science, and erosion. Within the statistical subproject, an MSc program in biostatistics was established mainly by strengthening human resources in statistics. A group of young academic staff members who graduated from the MSc program in statistics at Addis Ababa University (Ethiopia) obtained their PhDs in Flanders based on sandwich scholarships (see Section 3.2) and simultaneously took responsibility for several courses at Jimma University. During the PhD period, course material was developed by the PhD student, and in the first 2 years of the IUC, the courses were jointly taught by the PhD student and the Flemish PhD promoter, after which the newly minted PhD holder took full responsibility.

3. STATISTICAL CAPACITY-BUILDING THROUGH RESEARCH

Research in statistics is needed to develop in-country statistical expertise; to support scientific progress in a variety of disciplines; to support and advise policy makers; and to support

professionals managing crisis situations such as outbreaks of COVID-19, Ebola, and yellow fever. With the current global trend of data science and data use through big data platforms, and an emphasis on translational research, the South must be ready to collaborate with the North on an equal footing.

3.1. Time for Research and Research Culture Within Institutes

Research is a main objective of staff at universities and research institutes. But time specifically allocated for research is inadequate or nonexistent in the South. Researchers must find time for research as a personal initiative, as it is not programmed by the university. Ironically, many universities base promotion on research output, so it is crucial to lobby the institutional management to give a fair balance between time for teaching and time for research. Several universities have a research and higher degrees directorate, which could be a good platform to influence policy on time allocation.

This problem is often evident with staff who pursue PhD studies on a sandwich basis, whose teaching load can hamper their progress once they are in the South. There is, of course, the dilemma of staffing numbers, and having several staff on study leave at once poses a challenge. Departments could plan their staff training using a staggered model to avoid several staff being on study leave simultaneously, thus enabling teaching continuity but allowing research-based capacity-building. The situation is similar for other institutes where the institutional priority is to achieve set outputs, often not research-related.

3.1.1. Example 5: training of PhD students at Jimma University, Ethiopia. At the start of the 10-year IUC program (see Appendix A, Section A.1) between Jimma University and Ghent University (Belgium), 20 PhDs (3 in statistics) were planned for phase I (the first 5 years) based on sandwich scholarships. A plan was laid down for offloading the teaching tasks of the PhD students. As all were academic staff members with full-time teaching assignments, it was essential to get the support of the rectorate to reduce their teaching load to 20%. This plan was established at the university level but applied on an individual basis. Offloading was sometimes challenged at the departmental level, but never at the level of the rectorate. This strong support led to the success of the program, with most PhDs finished in 4 years, resulting in 60 completed PhDs (5 in biostatistics) at the end of phase II of the IUC program.

3.2. PhD Funding

Sandwich programs (for information on the grant format, see Example 6, Section 3.2.1) are becoming more and more attractive to countries in the South. In a typical sandwich program, a student works in his or her home country and travels once a year for a period of three months to the North, where he or she is supported by a northern supervisor. A sandwich program has important advantages over full-time PhD training in the North. First, students can work on topics relevant for their country, as fieldwork can be done locally. In the case of biostatistics, the student can communicate with colleagues in medicine or public health to delineate an interesting local problem and organize data collection. Second, the student receives a scholarship only while in the North, making the program more cost-effective. Third, the PhD students stay attached to their universities. Depending on the availability of a southern supervisor, the PhD student will obtain a double degree or a degree from the North only (see also the double-degree idea discussed in Example 6, Section 3.2.1).

However, the sandwich model also has drawbacks. The institute in the South may not have the capacity to supervise specific research topics, leading to little or no supervision for the student, who

by the nature of the program spends most of his or her time at the home university in the South. As stated above, due to limited manpower and little time for research, most of the students in sandwich programs will not receive full-time study leave, slowing down their progress. Often students make tangible progress only when they visit the collaborating institute, so offloading of teaching (see Example 5, Section 3.1.1) should be discussed with university management in the South.

In addition to sandwich PhD scholarship holders, more and more students from developing countries obtain 4-year PhD scholarships awarded by universities in the North to continue their academic education toward a PhD. In some disciplines, including statistics, northern universities need students from abroad to fill the available vacancies. We thus arrive at the sensitive topic of brain drain and the war for talent: A substantial portion of PhD students do not return to their home countries after they obtain their degrees. Duchateau & Janssen (2022) discuss the case of Ethiopian students trained in statistics, who all left for academic positions in other parts of the world.

3.2.1. Example 6: Flemish funding for sandwich grants. Belgian universities (in both the Flemish-speaking and French-speaking regions) support PhD students from developing countries by providing grants, one such being the sandwich PhD grant: Over a period of 4 years, the PhD student spends 12 to 16 months in Belgian universities (typically four periods of 3 to 4 months) with a grant for the time spent there and stays attached to his/her home university. Most universities in Flanders have dedicated budgets for this form of bilateral collaboration. Financial resources needed to support such students can also come from VLIR-UOS projects or from the Belgian Development Agency (**https://www.enabel.be/content/about-enabel**).

The optimal scenario for such students has three elements: The PhD topic should reinforce statistical capacity in the local university; promoters in the South and in Flanders should be responsible for the supervision; and, if possible, a double degree (a local and a Flemish diploma) should be awarded if the PhD trajectory has been successful. An advantage of this formula is that the PhD student stays linked to the home university—an important condition is that time to work on the PhD is guaranteed while there (8 to 9 months annually over 4 years) (see Example 5, Section 3.1.1).

3.3. African PhD Funding Approaches

African PhD funding approaches vary greatly. In Uganda, the training can take place fully in-country or in the North. In 2014, Makerere University (Uganda), through the Makerere–Sweden Research Program, won a 5-year Swedish International Development Cooperation Agency (SIDA)–funded grant to train staff from public universities in PhD education. There were various strands, including one in mathematics that targeted 20 PhDs, and through which some staff obtained a PhD involving statistical methodology. Prior to this, SIDA supported an East African regional program to train masters in mathematics.

In Ethiopia, the local and national grants are for training within the country. Academic staff members can enroll in a PhD program in statistics in Addis Ababa University or Hawassa University. The government has channeled some funding to award small grants and scholarships to university staff to pursue graduate studies within the country, but the money involved is very limited and cannot be used for conferences. Currently there is a special program and collaboration between the Ethiopian Ministry of Education, Jimma University, and Ghent University to train Jimma staff members in Belgium (NASCERE, the Network for Advancement of Sustainable Capacity in Education and Research in Ethiopia; see Example 7, Section 3.3.1).

South Africa has both capacity-building and research grants, the latter often with a capacity-building component. More and more, the training is in-country, with few participants going

abroad. The Building Academic Partnerships for Economic Development project, funded by the Belgian Development Agency, allows registration at a Belgian institute.

In Malawi, in-country training is the more common model. In Kenya, at Moi University, there has been funding through Brown University to train MSc and PhD students, but the training takes place at Brown. However, the program is implementing a sandwich PhD training model in the current cycle.

3.3.1. Example 7: Network for Advancement of Sustainable Capacity in Education and Research in Ethiopia. In 2017, a tripartite agreement between Jimma University, Ghent University, and the Ethiopian Ministry of Education was set up to involve 300 Ethiopian academic staff members in PhD training in Flanders. The ministry sponsors NASCERE through sandwich scholarships that allow the PhD students to spend time at a Flemish university, the supervision involves a South–North team, and a joint PhD degree is delivered by the Ethiopian and Flemish universities. Parallel to NASCERE, the ministry supports full-time PhD scholarships in India. The European sandwich scholarship and the Indian full-time PhD scholarship cost more or less the same, but the Ethiopian ministry decided to diversify the PhD training formats. Major advantages of the NASCERE scholarships are that PhD students remain attached to their home university and can deliver services, they work on problems relevant for the country, and PhD supervising capacity is built up at Ethiopian universities.

3.3.2. Example 8: Bongani Mayosi National Health Scholars Program in South Africa. The Bongani Mayosi National Health Scholars Program in South Africa is an initiative by the National Health Research Committee and a partnership between the South African National Department of Health, the Public Health Enhancement Fund, and the South African Medical Research Council (SAMRC). Its objective is to fund the training of 1,000 PhDs in health and clinical research over the next 10 years and, specifically, to build capacity in COVID-19 research and its impact on maternal neonatal and child health, communicable diseases, noncommunicable diseases, and health system preparedness and resilience to pandemic response (not restricted to COVID-19). This funding opportunity targets first-year PhD students in specialized medical and demographic research fields, including biostatistics and data science. Students in this program have supervisors at a South African university. In practice, many embark on collaborative PhDs with a cosupervisor from the North.

3.4. Project Funding

Funding for research in most African countries is a big challenge. Most support is external and/or international, with little or no local financial input. Institutes and countries are now budgeting funds for local researchers to study local problems, and several universities have a research and graduate studies directorate to manage internal, national, and international research grants and to write grant proposals to make research funds available to local staff. However, the importance of research in statistics to national development is often not appreciated, and it remains a challenge to get funding for research with statistics as the primary topic. Statistics is too often (but not always; see Example 9, Section 3.4.1) embedded as secondary research into another proposal. National efforts can also be restrictive when a fund is set up specifically for a certain research field, such as Uganda's presidential initiative, which prescribes particular topics of interest.

At the international level, research institutes and universities rely more on collaborative capacity-building or research grant funding from the NIH, the Wellcome Trust, the Gates Foundation, and other agencies. Such funds typically come with tagged topics.

3.4.1. Example 9: South African Centre for Epidemiological Modelling and Analysis postgraduate bursaries and other research funding. The South African Centre for Epidemiological Modelling and Analysis (SACEMA) is a national Centre of Excellence founded in 2006. It is funded by the Department of Science and Innovation, managed by the National Research Foundation, and hosted by Stellenbosch University (South Africa). SACEMA's mission is to improve health in Africa, and particularly South Africa, through epidemiological modeling and analysis. SACEMA offers funding for honors, master's, and PhD students in mathematics, epidemiology, biostatistics, global health, and biochemistry. SACEMA also offers funding for pre- and postdoctoral emerging researchers within South Africa via the Emerging Researchers Fund.

3.4.2. Example 10: Malawi National Commission for Science and Technology. There is limited local and national funding for capacity-building in Malawi. Through the Health Research Capacity Strengthening Initiative, a program hosted by the National Commission for Science and Technology, the Malawi government offered scholarships on capacity-building (2008–2014). One of the mandates of the initiative was to enhance institutional capacity for high-quality multidisciplinary health-related research studies. Capacity-building relies on grants for individuals or research institutes conducting research within Malawi, or on cooperation between governments. Cooperation fellowships include those offered through the British Council, such as Beit Trust and Commonwealth scholarships. The Beit Trust (**https://beittrust.org.uk**) annually awards master's and PhD scholarships for students from Malawi, Zambia, or Zimbabwe to study or research at universities in the United Kingdom, Ireland, or South Africa. The durations of scholarships in the United Kingdom and South Africa are 1 year and 2–4 years, respectively. Other organizations, such as the US National Institutes of Health (NIH), also provide cooperation fellowships. As a concrete example, two biostatistics PhD students from Malawi have been trained at WITS based on NIH funding for interdisciplinary training for malaria research, enabling them to develop independent research teams capable of designing, implementing, and analyzing results of locally and internationally relevant studies and to create a robust and sustainable graduate program in their own country.

3.4.3. Example 11: VLIR-UOS project funding. VLIR-UOS provides funding for academic collaboration on teaching, research, and transversal themes, the latter including library and information and communication technology, with a number of partners, including Kenya, Uganda, Ethiopia, South Africa, and Malawi. In Appendix A, we briefly describe the type of projects supported by VLIR-UOS. The following two examples illustrate how such projects contribute to statistical capacity-building in research.

The first example is a North–South–South project combining expertise from different countries in the South and Flemish universities for research or educational objectives. In two phases (2011–2014 and 2014–2017), the expertise in experimental design from Jimma University, the Escuela Superior Politécnica del Litoral (Ecuador), and the National Agrarian University–La Molina (Peru) was connected with that of Flemish team members to improve the support that statisticians offer to researchers (e.g., in agriculture) to design their experiments.

The second example is a project on PhD studies in statistics in the context of a multidisciplinary IUC program with Jimma University (see Example 4, Section 2.2.4). Within the statistical subproject, PhD topics were generated by the scientific questions arising during the research on the dam. To study the effect of the dam on malaria incidence, for instance, new statistical methodology was developed (Getachew et al. 2013). All the aforementioned PhDs had an attachment to other investigators, with mutual benefits for all partners.

3.5. International Research Collaboration

A top priority of the academic community is to share scientific findings, through publications in scientific journals, networking, exchanges at conferences and workshops, and international collaboration (e.g., research visits and sabbatical leave). In this section, we reflect from an African perspective on such research opportunities, the importance of networks, and the role that can and should be played by statistical societies.

3.5.1. Networks. Networks are crucial for sharing experience and building capacity by bringing together academic and research institutes to answer research questions. They provide opportunities to share South–South and/or South–North research expertise and are the cornerstone for graduate programs and for organizing advanced short courses and workshops. A network like SUSAN (see Example 12, Section 3.5.2) can play an important role in statistical capacity-building by putting interdisciplinarity high on the agenda. Its recently developed mentorship program (see Example 17, Section 4.4.1) is another avenue to improving research capacity.

3.5.2. Example 12: Sub-Saharan Africa Network within the International Biometric Society. SUSAN of the IBS is a network of national/regional biometric groups of sub-Saharan African countries that promotes the advancement of life sciences through the development, application, and dissemination of mathematical and statistical methods. This includes applications in agriculture, medical and health research, infectious diseases, environment and ecology, climate, and other applied sciences such as statistical genetics and bioinformatics (**https://www.biometricsociety.org/about/regions-networks/susan-network**). An important activity is the biennial conference started in Kenya in 1990. Recent conferences have been held in Kampala, Uganda (2015); Lilongwe, Malawi (2017); and Cape Town, South Africa (2019). In 2021, Kenya hosted the seventeenth biennial conference, Biometry in the Era of Big Data for Health and Food Security. The main topics of the conference (genetics/bioinformatics, data mining, infectious disease modeling, causal inference, climate change, machine learning/artificial intelligence, environmental statistics, global health and food security, etc.) make it clear that a lot of attention is paid to trends that color modern (bio)statistics.

3.5.3. Statistical societies. International statistical societies should play an important role in statistical capacity-building. They are driving forces in pushing statistical methodology toward new frontiers, so that the ever-increasing complexity of massive data sets can be handled. They promote statistics as a key tool in a large variety of scientific domains, including public health in its different aspects (epidemiology, genetics, pharmacology, clinical studies, etc.). At the same time, societies can play an important role in intertwining innovation in methodology and societal impact, taking into account the local situation and needs. It is therefore important to note that one of the goals in the strategic plan (2017–2021) of the International Statistical Institute (ISI) was to promote and deliver capacity-building workshops and activities that served the needs of the statistical community, especially from developing countries. The 2013 ISI white paper (Teugels et al. 2013) on statistical capacity defines the objectives as enabling statistical practitioners in the public and private sectors to use state-of-the-art methods for data collection, analysis, and interpretation, and contributing to the development of statistical infrastructure and human resources in official, survey, and business statistics, as well as in statistical education and research. The ISI Committee on Statistical Capacity-Building advises the ISI Executive Committee on the planning of appropriate initiatives. One priority of the 2022–2025 ISI strategic plan is to support ISI members in networking, particularly at a regional level, with a focus on supporting members in countries in developing regions, developing online communication platforms, and enhancing the impact and

legacy of statistical conferences. In doing so, equitability and ownership have become important keywords. The January 2022 call of the ISI Short Course Committee to submit proposals for short courses is an example of the practical implementation of this idea. Such course material can be used to create online communication platforms in line with our discussion on digital education (Example 3, Section 2.2.3). Some statistical societies also provide grants for members in lower- and middle-income countries to present their work at international conferences.

At a local level, societies in the South are a good avenue for dissemination of research findings. Most such societies organize research conferences and short courses, which also provide networking platforms, at least once a year.

3.5.4. Example 13: South African Statistical Association. The South African Statistical Association publishes the *South African Statistical Journal* and manages its annual conference, which is used as a platform for capacity development via preconference workshops. The association was also instrumental in creating an accreditation for statisticians (through the Institute of Certificated and Chartered Statisticians of South Africa) and also offers bursaries and awards.

Ideally, local societies should play a bigger role, but they often lack resources. They would be well placed to raise awareness on the importance of statistics at the national level, could engage and lobby governments for funding, and could provide platforms for networking, leading to development of fundable proposals.

4. STATISTICAL CAPACITY-BUILDING TROUGH CONSULTING

4.1. The Applied Dimension of Statistical Training

Biostatistical consulting has a critical role in ensuring that medical studies are well designed and that the findings are rigorously established. Indirectly, it underpins high-quality and usable scientific literature in biometry, sociometry, econometrics, quantitative psychology, and medical and life sciences research. It is crucial that biostatisticians are adequately equipped with methodological knowledge, applied insight, and communicative fluency to ensure high-quality consulting. A barrier to this could be research-centered master of statistics degrees, delivering graduates who are experts in one field but have limited knowledge in basic statistical methodology. While several universities within Africa also organize a master of statistics/biostatistics program with a coursework focus, there is still a need to address this skills gap for consultants who obtained their degrees in mathematical statistics or via research-centered programs. This deficit can be addressed by companies and institutes budgeting for staff to attend virtual or in-person short courses, master-level courses at universities, and preconference courses and workshops. In addition, in view of our rapidly developing field, lifelong training of all consultants is essential.

4.1.1. Example 14: statistical capacity enhancement in the South African Medical Research Council. At the Biostatistics Research Unit of SAMRC, part of the annual budget is allocated to capacity development of staff, and performance contracts of staff members include personal statistical capacity-building as a key area for junior- to mid-career-level statisticians, measured through the successful completion of short courses and application of this new knowledge in daily work. At the start of each year, staff identify new or existing skills that they wish to enhance and discuss them with their managers. Such capacity enhancement ensures the ongoing professional growth of statistical consultants.

4.2. Statistical Consulting in Master of Science Training

Statistics degrees that focus on theoretical components with little attention to applications are a barrier to grooming good biostatistical consultants. The theoretical foundation of statistical

methodology remains important but must be balanced with applied insight. Graduates in statistics sent into industry or government organizations should have in-depth knowledge of applied aspects of topics, such as sample size calculation for clinical studies, longitudinal data analysis, Bayesian analysis, spatial modeling, and basic programming. A course in consulting should be offered in master's programs to give students insights into how to approach study design, the relevant questions to ask a researcher, what methods might be appropriate, how to estimate the time cost for a project, and how to provide a reproducible report of the results. Such courses not only will improve the consultancy capacity of the students but also will, in the long run, increase demand for biostatisticians in the scientific research community.

4.2.1. Example 15: statistical consulting at University of the Witwatersrand. A statistical consulting course is provided at WITS within the MSc (biostatistics) program. The course, entitled Statistical Consulting in Health Research, has been compulsory since 2015. Its aim is to introduce students to practical issues from study design, data collection, analysis, and report writing. It provides training in consulting on the statistical aspect of research problems arising in the biomedical field. Initially under the close supervision of a staff member, students participate in discussions with investigators, leading to the design and/or analysis of a quantitative investigation. The module includes writing reports for scientific journals, managing research collaborations, consulting with clients, giving oral presentation of results, and role-playing as practicing statisticians. By the end of this module, students should be able to critically evaluate published research. Assignments based on real consulting problems are part of the curriculum.

4.3. Responding to the COVID-19 Outbreak

During the COVID-19 pandemic, both policy makers and the public showed increased interest in and appreciation of the ability of statistics to predict cases and deaths and to support the design of vaccine efficacy studies and therapeutic trials. This opened new opportunities but has made the shortage of biostatisticians in Africa prominent. The COVID-19 outbreak also illustrates misconceptions about what statistics is and what it can achieve and has affected trust in statisticians, who are required not only to conduct analyses for the scientific community but also to report findings for policy makers and the general public. Statisticians play a key role in national policy, providing data-driven answers to questions and providing reliable information to the public.

4.3.1. Example 16: South African COVID-19 Modelling Consortium. the South African COVID-19 Modelling Consortium is a group of researchers from academic, nonprofit, and government institutes across South Africa, coordinated by the National Institute for Communicable Diseases, on behalf of the National Department of Health. Its mandate is to provide, assess, and validate model projections to be used for planning by the Government of South Africa. The group includes researchers from the Modelling and Simulation Hub Africa at the University of Cape Town, the Health Economics and Epidemiology Research Office at WITS, SACEMA at Stellenbosch University, and the National Institute for Communicable Diseases. The group was formed in March 2020 and has been instrumental in the government's response to the pandemic, disseminating their model predictions through formal reports and media briefings as well as social media and a website with an interactive dashboard developed in 2021 (SACMC Epidemic Explorer, **https://sacmcepidemicexplorer.co.za**). It supported the South African response in a number of ways, including early modeling to show the urgency of intervention, projection updates to support resource management, and development of metrics to monitor for epidemic resurgences and for the emergence of new waves.

4.4. The Growth Curve of a Statistical Consultant

Statistical consultants working at research institutes are often quite overwhelmed by their workload and have little time for research. This may impede their intellectual growth, particularly while pursuing their doctoral studies. Consulting can also facilitate research, often by allowing the biostatistician to be exposed to complex analytical projects which cannot be analyzed using standard methodology.

An alternative and interesting combination is when the consultant statistician teaches a course at a university. Such a teaching assignment can serve two purposes: It can bring a consultant-oriented course to the university program (as discussed in Section 4.2), and/or it can give the consultant the opportunity to gain in-depth insight into a new topic through teaching.

Although biostatistical skill is scarce in Africa, its renumeration, particularly in the public sector, may be substantially lower than in the financial industry or elsewhere, leading to high turnover of well-qualified staff. Responses to this threat include a scarce skill allowance over and above the standard renumeration, or employers allowing a well-defined amount of time for employees to serve as independent consultants.

Mentoring and job shadowing are crucial to help early-career biostatisticians learn how best to conduct statistical consulting and how to work as part of a team. This has been noted by several master of statistics programs that include a well-guided internship period of up to 6 months at a research institute. There also exist specific funding streams that cater to this purpose, such as HIV Trust biostatistics fellowships and NIH National Cancer Institute biostatistics fellowships.

As presented in Section 2, high-quality academic teaching is critical for the development of statisticians, but some key skills are not easily acquired in academic settings, including knowledge of a particular health research area (e.g., HIV), leadership skills, time management, and cross-functional collaboration. Senior statisticians have a wealth of knowledge that can guide a mentee through the early phases of his or her career. Odueyungbo & Thabane (2012) have emphasized the importance of mentoring in statistics and have offered guidance on how statistical departments, societies, and employers can best approach this. We recommend that mentors and mentees be carefully paired/linked based on the goals of the mentee.

4.4.1. Example 17: Sub-Saharan Network mentor-mentee initiative. In line with the IBS Mentoring Program (**https://www.biometricsociety.org/education/mentoring**), SUSAN launched a program at its 2021 conference in order to connect mentors and mentees in biometry, statistics, and data science. In the first step, mentors were approached by the SUSAN 2021 Local Organizing Committee, and each provided a bio-sketch and areas of expertise. This was followed by the mentees each completing a form with several key questions, including the following:

- What duration of mentorship do you seek?
- What are your areas of interest or specialization?
- What are your top two concerns with regard to pursuing a career in research or academia?
- Do you have a specific mentor you would like to work with?

In the third step, the committee members will assign mentors to mentees based on the data obtained in the first two steps, in order that at least 20 mentor-mentee pairs commence by September 2022. The committee is developing guidelines for goal setting and quarterly evaluation and will set up a website, hosted by the IBS Kenya.

5. CONCLUSION

To contribute to solutions to global challenges as equal partners, southern countries more than ever need to reinforce statistical capacity and expertise. Statistics is an indispensable tool that not only supports the work of scientists but also plays a fundamental role in data science and in evidence-based policy making. Statisticians in southern countries are well aware of their role in challenging times and work very hard to build the capacity needed in universities and research institutions. Although the approach taken in this article is positive, several hurdles still remain, such as a lack of national funding for statistical projects, ownership of data by southern partners, competitive remuneration in light of the worldwide battle for talent, and scientific visibility of southern (statistical) research in high-impact journals. We strongly believe that South–South and South–North collaboration on statistical education, research, and consulting is essential for making progress and removing obstacles.

APPENDIX A: VLIR-UOS

In the Flemish region of Belgium, VLIR-UOS is the main vehicle for (inter)university cooperation for development. VLIR-UOS is the Higher Education Cooperation for Development section within the Flemish Interuniversity Council. Its counterpart in the French-speaking region of Belgium is the Académie de recherche et d'enseignement supérieur (**https://www.ares-ac.be/fr/cooperation-au-developpement**). VLIR-UOS covers the spectrum from formulating the policy plan, defining different intervention types, launching open and competitive calls, selecting projects (based on the binding advice of an committee of independent international experts), monitoring, and evaluation to accountability and collective learning. Its governance is in the hands of its bureau, with representatives from the Flemish universities and university colleges supported by a secretariat in Brussels. This approach stimulates institutes in their cooperation for development ambitions. The federal Ministry of Development Cooperation provides an annual budget of €32.5 million to VLIR-UOS to realize a 5-year program.

Starting from the baseline of "sharing minds, changing lives," VLIR-UOS supports partnerships between universities and university colleges, in Flanders and in partner countries, looking for innovative responses to global and local challenges. It stimulates partnerships between professors, researchers, and lecturers and awards grants to students and professionals in Flanders and partner countries. VLIR-UOS helps reinforce higher education in partner countries and aids the development-relevant internationalization of higher education in Flanders (**https://www.vliruos.be/en/about_vlir_uos/2**).

VLIR-UOS supports two pathways of change: developing higher education institutes as drivers of change through partnerships and developing individuals as agents of change through scholarships. Most scholarships are embedded in partnerships, with individual scholarships being more limited in number. In what follows, we briefly provide information on the VLIR-UOS portfolio.

A.1. Project Funding

Project funding is used to support partnerships between universities and university colleges (applied sciences and arts) and to build bridges between higher education institutes and governments, NGOs, and business partners in Flanders and 17 partner countries (**https://vliruos.be/en/countries/96**).

The flagship of the project portfolio is the IUC programs, which run over two 5-year periods (€550,000/year). From the examples given in the text, it is clear that such long-term interventions provide valuable opportunities for statistical capacity-building. For information on other

intervention types (South initiatives, international training programs, TEAM projects), readers are directed to **https://www.vliruos.be**.

A.2. Scholarships

ICP Connect is the main scholarship program. Such programs are Flemish-accredited international study programs organized at one or more Flemish universities. The programs focus on subjects aligned with the UN Agenda 2030 and Sustainable Development Goal principles. VLIR-UOS supports 15 ICPs, each with an annual intake of 10 new first-year scholars from one of the 29 scholarship countries (**https://vliruos.be/en/scholarships/6**). The ambition is that the resulting graduates will be critical global citizens and change makers. One-year programs can apply for up to €500,000/5 years and 2-year study programs for up to €750,000/5 years.

VLIR-UOS also supports students from the European Economic Area enrolled at a Flemish university or university college to have internships at southern institutions. Two other important programs are the Global Minds program, which enables Flemish higher education institutes to operate as drivers of change for sustainable development (€24 million/5 years), and the Bridging Science-Society program, which facilitates connections within and beyond the VLIR-UOS community through exchange platforms, networks, and multistakeholder partnerships engaging academic, public, private, and civil society actors (€2 million/5 years).

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