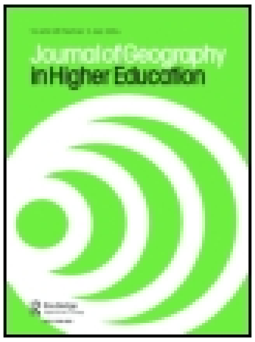

Journal of Geography in Higher Education

ISSN: 0309-8265 (Print) 1466-1845 (Online) Journal homepage: https://www.tandfonline.com/loi/cjgh20

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To cite this article: Neema S. Sumari, Zhengfeng Shao, John L. Van Genderen, Walter Musakwa, Fanan Ujoh, Prosper Washaya & Trynos Gumbo (2019): Status of geoinformatics education and training in Sub-Saharan Africa: initiatives taken and challenges, Journal of Geography in Higher Education, DOI: 10.1080/03098265.2019.1599831

To link to this article: https://doi.org/10.1080/03098265.2019.1599831

Published online: 11 Apr 2019.

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JOURNAL OF GEOGRAPHY IN HIGHER EDUCATION
https://doi.org/10.1080/03098265.2019.1599831

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ARTICLE

Status of geoinformatics education and training in Sub-Saharan Africa: initiatives taken and challenges

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ABSTRACT
This paper presents an update on some of the activities that have taken place since a World Bank report; "Guidelines for Education and Training in Environmental Information Systems in Sub-Saharan Africa: Some Key Issues" was published and provides details on the current situation. It shows how organizations such as the African Association on Remote Sensing of Environment, International Society of Photogrammetry and Remote Sensing, European Association of Remote Sensing Companies, Group on Earth Observation, and several others have helped to increase manpower resources in the region and strengthened institutional capacity in the field of geoinformatics, through capacity building, technology transfer, international cooperation and the provision of internal African resources. After reviewing what has happened in the field of geoinformatics education and training, we focused on current initiatives taken and challenges in five Sub-Saharan countries: Ethiopia, Nigeria, South Africa, Tanzania, and Zimbabwe. We reviewed GIS education and training in the private sector, government, information communications technology in higher education institutions, GIS application areas and challenges facing GIS education and training. Findings show that; change should involve education stakeholders in all levels of education and curriculum quality, regional and international cooperation through exchange programs, should be a priority for Sub-Saharan Africa countries.

ARTICLE HISTORY
Received 14 October 2017
Accepted 23 March 2019

KEYWORDS
Sub-Saharan Africa; education; training; geospatial information; geoinformatics; Geographic Information Systems (GIS)

Introduction

Geospatial information technology is a tool that has permeated society over the past two decades. Geospatial information is supposed to lead to a better future according to the United Nations Geospatial Information Committee. For this to occur Geographic Information Systems (GIS) has to be taught in institutions of higher learning and adopted by citizens. Geospatial information has its origins in North America and is now part of everyday life and developing countries have also realized the potential and utility of geospatial information science. Consequently, GIS is now being taught at

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universities, higher education institutes, high school and community level in developing countries. Progress in geospatial technology has been immense since the days of using GIS on a mainframe computer to web GIS, GIS clouds and where data are accessible and can be easily shared. In developing countries, GIS pedagogy and how it is taught in class has not kept pace with rapid GIS developments. Consequently, this paper discusses the status of geoinformatics education and training in Sub-Saharan Africa focusing on English-speaking countries in West, East and Southern Africa. Five countries have been selected as typical examples of Sub-Saharan countries trying to increase their use of GIS technology.

Geographic Information Systems (GIS) is a computer-based tool that is designed to capture, store, manipulated, visualize, analyse, manage, and present geographical data (Li, Wang, Dong, Shen, & Shi, 2017a; Li, Wang, Shen, & Dong, 2017b). GIS technologies have been used since the 1960s for town and spatial planning (Di Gregorio et al., 2015), earth observation operations (Guo, 2016), epidemiological mapping, environmental applications and for transportation applications. Generally, the applications of GIS have been used to display various phenomena that have a spatial location. However, with advances in technology, data management and subsequent availability, GIS technology has the ability to be integrated and applied as a tool for both solving problems and decision-making processes in social services delivery, evaluation, and change management applications (Ehlers, 2008; Li, 2003; Li & Shao, 2009). Currently, some global issues such as natural disasters (e.g. floods and earthquakes), weather forecasting, water resource management, and land use planning require universal, multifaceted, location-based knowledge that can only come from a GIS (Future Earth, 2014; Guo, 2016). Therefore, GIS can be applied as a tool for both problem-solving and decision-making processes, as well as for visualization of data in a spatial environment from a station or a Global Navigation Satellite System (GNSS) location. It also appears that the opportunities for GIS applications are endless as new possibilities continue to emerge such that GIS pedagogy and how it is taught often lags behind in particular in Sub-Saharan Africa.

To utilize this technology. in Sub-Saharan Africa, much more emphasis needs to be placed on education and training. Anderson (2003) poses the question, "how much GIS should students know, how should they use it, and how long will the operational skills persist in the minds of the learners?" In 2012, Coetzee and Eksteen (2012) discussed this topic in depth on "how the ability of students to use GIS to attain the goals of geography remains largely unknown". The effectiveness of practising GIS has been analysed in more detail in a recent study (Belgiu, Strobl, & Wallentin, 2015). According to the World Bank Report of 1992 (van Genderen, 1992), there was insufficient GIS knowledge in Sub-Saharan Africa at that time as most of the schools had no GIS software and hardware. The costs involved, the time to prepare GIS-based lessons and the lack of institutional support were all key constraints at that time. However, nations need to provide appropriate macro-control measures, and give appropriate guidance, regulations, and support. In the GIS industry, educators need to study continuously the development of the discipline, increase the scientific quality, actively cooperate with the reform of state education systems, discuss new ideas, new modes and new methods, be good at encouraging students interested in learning and innovation, train qualified and talented individuals in GIS and promote hi-tech development strategies . We should also encourage self-study by using technology to encourage understanding as well as discovery, which will allow higher quality and more efficient work to be produced (Li, Gong, & Yue, 2014; Sife, Lwoga, & Sanga, 2007; Eksteen et al., 2015).

Similarly, Bennett, Ogleby, and Bishop (2009) show how the demand for graduates in geoinformatics is increasing globally, but enrolments in such courses are remaining static. They present a new model for ensuring more students select geoinformatics to meet a social need. In general, the majority of these studies indicated that education and training in geospatial information science are effective, especially by making geography lessons more visually appealing, student-catered and desirable and thus increase students' achievements (Kerski, Demirci, & Milson, 2013; Knight, 2018; Li & Chen, 2017; Muniz, Demirci, & Van der Schee, 2015). Likewise, van der Heiden, Pohl, Bin Mansor, and van Genderen (2015), apply a similar methodology and pose questions on the location of the training, who and what should be taught and why and the target audience of the training. In relation to establishing sufficient learning, they pointed out that this forms an integral part of a nation's ability to establish and cultivate such absorptive capacity on a national or an organizational specific level. They stressed the need to develop national and regional policy guidelines for the key decision makers involved in education and training.

Another study recently carried out in South Africa and Zimbabwe (Musakwa, 2017) profiles the usage of GIS in two cities, namely, Bulawayo in Zimbabwe and Ekurhuleni in South Africa. The results indicate that considerable progress has been made in the application of GIS in municipal planning. However, there are still some impediments limiting the full utilization of GIS in local municipalities. These impediments include inadequate GIS curricula in undergraduate programs, lack of resources and lack of political will. According to the United Nations' Sustainable Development Goals, Africa faces the greatest challenges in this regard, with nearly 7 in 10 countries experiencing acute shortages of trained teachers in the field of geoinformatics. In 2013, only 71% of teachers in sub-Saharan Africa and 84% in Northern Africa were trained with respect to geoinformatics education.

Accordingly, this paper investigates and presents the current status and initiatives of geoinformatics education and training in Sub-Saharan Africa in five Sub-Saharan countries, namely, Ethiopia, Nigeria, South Africa, Tanzania, and Zimbabwe (Figure 1). The current status and initiatives on GIS education focuses on reviewing GIS education and training in the private sector, government, information communications technology in higher education institutions, GIS application areas, and challenges facing GIS education and training. Finally, recommendations on how education and training can be improved in Sub-Saharan Africa, based on the case study findings. In-depth investigations were done in each case study by consulting secondary data sources that include records from different government departments and training organizations such as universities and colleges.

Recent efforts taken to advance geoinformatics in Sub-Saharan Africa

This section provides a rundown of efforts that have been put in place to advance Geoinformatics in Sub-Saharan Africa. The section will introduce the African Association on Remote Sensing of the Environment (AARSE) and its objectives and discuss the contribution that the International Society of Photogrammetry and Remote Sensing (ISPRS) has made to education and training to Sub-Saharan Africa. The section will then go on to give a summary of the role of the commercial sector in the strengthening of capacity in Africa and finally explore the initiative made by the Group on Earth Observation (GEOwha) in Africa.

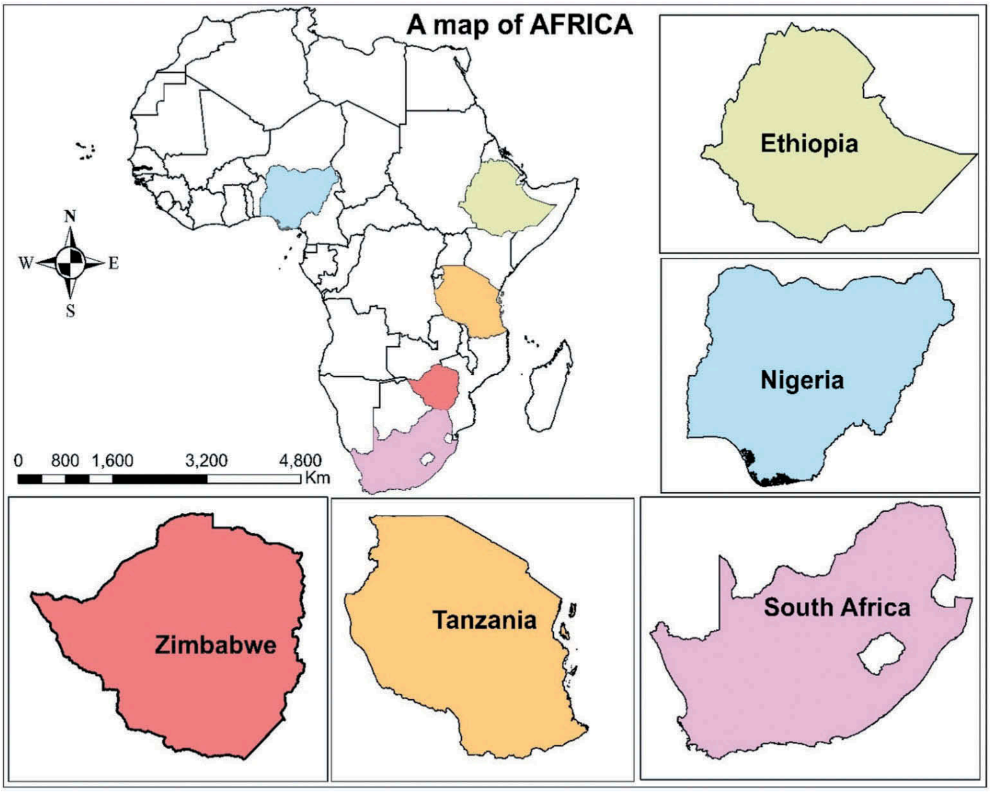

Figure 1. A map of five Sub-Saharan countries.

The African Association on Remote Sensing of Environment (AARSE)

This academic/scientific society was officially founded in 2008, although they had been carrying out activities since 1992; more than 30 African nations are currently members (Asiyanbola, 2014; van Genderen, 1992, 2017). The Society is a regional associate of the International Society of Photogrammetry and Remote Sensing. It also collaborates with several other international societies and organizations such as the IEEE Geosciences and Remote Sensing Society (GRSS), the European Association of Remote Sensing Laboratories (EARSeL), as well as several others. AARSE is also a participating member of GEO (Group on Earth Observation), and was an institutional member of GSDI (Global Spatial Data Infrastructure) Association (until GSDI was dissolved as a legal entity in October 2018), as well as various U.N. committees in Africa such as the UN-ECA's sub-committees on geoinformation. The principal objective of the association is to raise awareness about the benefits, products and services offered by earth observation and geospatial technologies to government departments, industry, universities and society. Its three main objectives are to (i) promote the advantages and applications of remote sensing and GIS for African economic development, (ii) improve the teaching of earth observation and geospatial technologies at African universities by providing better case studies, teaching materials and helping teachers improve their syllabuses,

(iii) exchange views with all relevant stakeholders about the practical applications of remote sensing and GIS of specific relevance to African conditions.

ISPRS's contribution to education and training in Sub-Saharan Africa

The International Society of Photogrammetry and Remote Sensing is a global international society, established over 100 years ago. Although there has been great growth in enhancing geoinformation over the past few years, this is still mainly limited to Western countries and to some Asian ones (Chen et al., 2016). Hence, ISPRS has been supporting the African Geospatial Sciences Institute (AGSI) as well as the AARSE, to develop an educational curriculum, based on the needs of the African region. They developed a framework for this curriculum, and have identified a set of modules, as well as identifying some key issues (Dowman & Labbassi, 2014). The ISPRS has developed a new vision for further development of Geoinformatics education, as shown in Figure 2.

The role of the commercial sector in the strengthening of capacity in Africa

Gyamfi (2011) identifies three components in capacity building: (i) providing necessary infrastructure, (ii) improving the understanding of the value of geospatial data to support

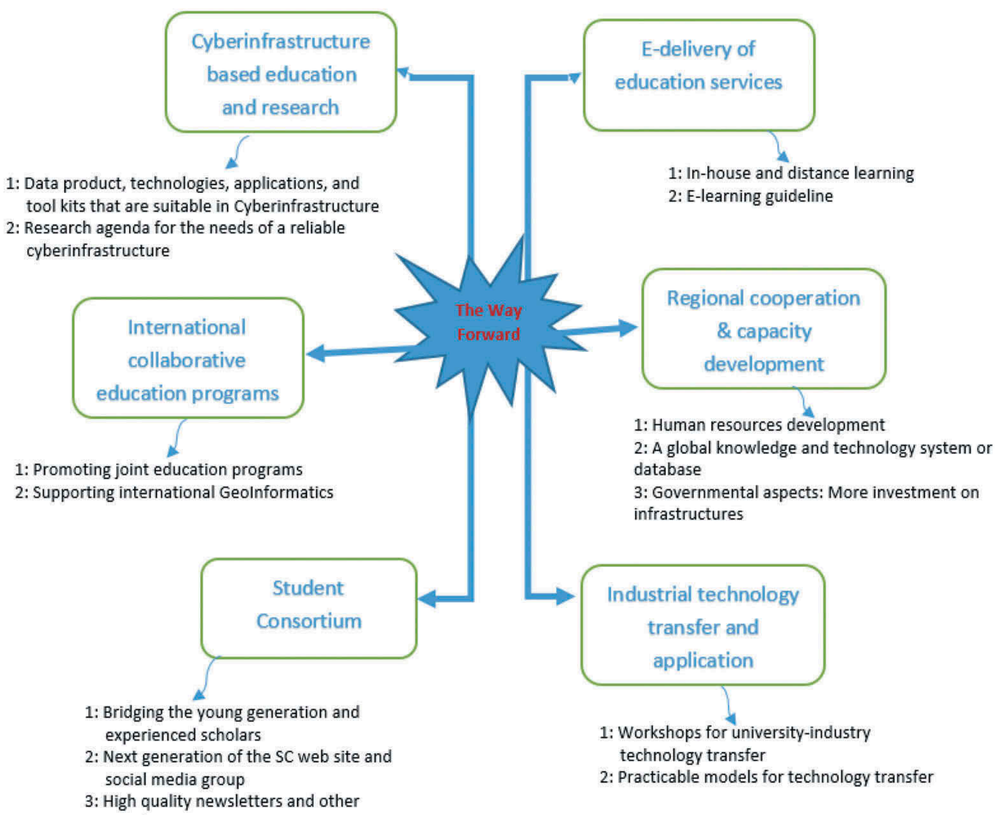

Figure 2. The ISPRS Vision for Geo-informatics Education (Modified from Gong et al., 2017).

decision-making and (iii) having suitable levels and quality of education and training to meet geo-labour market demands. These components, while also implementing necessary changes, will also stimulate further growth through the endorsement of digital earth technologies for spatial data infrastructure. The geospatial industry believes that the educational institutes in Africa need to adopt more innovative approaches to embrace the rapidly changing scientific, geospatial education landscape. Professionals in the commercial sector in Sub-Saharan Africa, with experience in dealing with GIS education in the professional academic domain, have helped to train more GIS users at universities. However, the education system is unlikely to improve unless a curriculum framework for GIS is established with clear guidelines on minimum course requirements for undergraduates for university-level programs that are subject to evaluation (Kumar, Siddiqui, Gupta, Jain, & Murthy, 2014; Whyatt, Clark, & Davies, 2011). The European Association of Remote Sensing Companies (EARSC), based in Brussels, Belgium, has also started some initiatives in Africa, for example, by twinning some European companies with African companies to enhance their ability to carry out remote sensing and GIS projects in Africa.

An initiative of GEO (The Group on Earth Observation) in Africa

GEO recently launched a survey on earth observation, which will contribute to the African Union Space Programme, and assist in preparing an Earth Observation Capability Audit for Africa. The African Space Policy and African Space Strategy was approved by the African Union (AU) Summit in January 2016 (Anderson, Ryan, Sonntag, Kavvada, & Friedl, 2017). An additional resolution of the AU Summit mandated the AU Commission, through a formal AU Space Working Group (AUSWG), to develop an Implementation Plan and Governance Framework for the African Space Programme (Belgiu et al., 2015). The resulting roadmaps prepared for the development of the Implementation Plan and Governance Framework are quite complex. These roadmaps cover the four space aspects of: (i) earth observation, (ii) navigation and positioning, (iii) satellite communications, and (iv) space exploration. The implementation plan and governance framework produced by AUSWG, were required to focus on 16 key priority areas that are considered for the socio-economic development of the African continent, namely: disasters; health; energy; climate; water; weather; ecosystems; agriculture; biodiversity; peace, safety, and security; human migration and settlements; education and human resources; communications; trade and industry; transport and infrastructure (Scott & Rajabifard, 2017).

Current situations in Sub-Saharan Africa

In this section, we give details of what is happening in the five selected English language countries in Sub-Saharan Africa listed previously, one from West Africa, Nigeria, three from East Africa Ethiopia Tanzania Zimbabwe, and South Africa in Southern Africa. We have not considered the status of geoinformatics education and training in the Francophone or Portuguese-speaking countries. These represent countries with varying levels of adoption of geoinformation technology and applications into their tertiary education system.

Ethiopia

Ethiopia has been known for poor economic and technological performances (Hastings & Clark, 1991), particularly during the 1980s and 1990s decades when it experienced infamous famines and political instabilities.

Private and government sector involvement

The private sector in Ethiopia has been mainly investing GIS and RS technologies for consultancy work on environment management. The technology has also been invested in health monitoring and management (Bailey et al., 2011). The Ethiopia Strategy Support Program (ESSP) has been offering GIS short training courses and one of these was conducted at the Wondo Genet College of Forestry and Natural Resources, which is part of Hawassa University. The training courses have also been offered to the Central Agency, the National Meteorological Agency as well as others. Government have been targeting most of the government employees to equip them with the basic principles of GIS and its applications.

IT infrastructure and applications in higher education

Alongside the impressive economic performance during the past two decades, the country's higher educational institutions have also been transforming not only their own systems but also their programs. Several improvements have been noted in the adoption and use of innovative technologies in GIS and RS. Among those universities that have improved their degree programs and are offering fully fledged and stand-alone GIS degrees programs are Haramaya, Mekelle Universities and Addis Ababa University (AAU).

First, Haramaya University has a degree program in GIS. The unit trains and produces graduates that specialize in geo-environmental and earth sciences. The university has made huge investments in computers and GIS labs, with very low ratios of computers to students that signify very good access to technology and GIS training. There are also classroom and other equipment sets such as LCDs, GPS receivers, digitizers, scanners, plotters, printers, compasses, and network modems. This has enabled the university and relevant department to produce graduates that are skilled and competent to manage and analyse spatial data, establish geo-databases and integrate GIS with RS. Second, Mekelle University set up the Institute of Geo-Information and Earth Observation Sciences in 2011 that specializes in spatial data infrastructure technology, and information systems for spatial and temporal data integration and image extraction. The institute has greatly transformed the teaching and learning of GIS and RS in the country. Third, Addis Ababa University (AAU), has successfully infused and taught GIS and RS in a variety of degree programs and short learning courses to keep abreast with transforming educational skills set. To start with, the five-year degree program in Urban and Regional Planning uses GIS in parts of its urban projects. Learners use GIS tools to undertake and complete their neighbourhood design, extension of existing city planning, urban redevelopment and the development strategies for small towns.

The application of GIS has mostly been in the agriculture sector, which is the mainstay of the Ethiopian economy (Feoli, Vuerich, & Zerihu, 2002). GIS has mostly been applied to crop management (Senay & Verdin, 2014), analyse land use cover and land use change, drought assessment (Legesse & Suryabhagavan, 2014), as well as for monitoring wood and forests. The technology is also being applied in urban development and environmental management (Feoli et al., 2002). The technology is also used to assess natural hazards (Temesgenab, Mohammeda, & Kormea, 2001) such as landslides (Bekele, Francesco, Giandomenico, Mohammed, & Asfawossen, 2010) floods, fire outbreaks. Lastly, GIS is applied to monitor animal movement, landscape evolution and in modelling soil changes (Reusing, Schneider, & Ammer, 2010).

Challenges

Similar to any other emerging country within the developing world, the country still faces many challenges concerning education and training, and applications of GIS and RS. Teaching and practice of GIS and RS have not been well established and spread across the country. Besides, there is very little scholarship in GIS and RS. This has resulted in low awareness and understanding of the technology among the majority of professionals within government, private sector and civil society organizations that could benefit from the technology. Technology is still very expensive, particularly the software packages and training courses as well as programs in GIS and RS, hence the public has a low-level of appreciation and interest in GIS and RS. The lack of effective and efficient infrastructure for storing, analysing and disseminating the GIS and RS data is one of the critical challenges in that country.

Nigeria

Private and government sector involvement

Over the course of 15 years since Nigeria's first earth observation satellite was launched in September 2003, there have been a number of changes in Nigeria's Surveying and Mapping industry especially with the introduction of satellite mapping. The National Geospatial Data Infrastructure is currently under development but not yet completed. Adeoye (2006) and Asiyanbola (2017) argued that current and expected changes in the sector are driven by several factors including the importance of spatial data infrastructure as a basic component for good governance and resource planning/availability.

Nigeria's private sector participation in Geoinformatics is not yet fully realized due largely to the fact that the National Geospatial Data Infrastructure, a basic geographic data framework upon which the industry is expected to thrive, is not completed. Perhaps this is the singular most constraining factor hindering the expansion and commercialization of the geospatial service sector in Nigeria. Currently, commercial participation in the geospatial sector in Nigeria is not considered profitable, even though there is a high need for services for informed planning and development, particularly for urban services, and the agriculture and transportation sectors, where improved services are needed to meet the annual population growth rate of 3.1% stipulated by Nigeria's National Population Commission (2007). Although the potential for private sector participation remains high, funding to the sector is not readily available as it is deemed non-profitable due to the absence of a clear and concise guiding framework for both content and products. In spite of the problems listed above, the private sector continues to engage in the establishment of small training centres, and through the sale of low-level equipment such as hand-held GPS receivers, etc.

The Nigerian Government began its investments in the remote sensing field with the establishment of the National Space Research and Development Agency (NASRDA) on 1 August 2001. Although Universities and Polytechnics pioneered geoinformatics education in Nigeria, the Federal Government of Nigeria (through NASRDA) have created a much more significant impact on geoinformatics education and application in the country given its access to relatively large resources (Federal Government of Nigeria, 2015, 2016, 2017). The launch of Nigeria's satellite missions has greatly influenced the wave of expansion in the RS and GIS education/training and application. NASRDA began its satellite missions in 2003 with the launch of Nigeriasat-1 (resource mapping and observation). Later in 2011, the Nigeriasat-2 and Nigeriasat-X (both for observation and resource mapping) were developed and launched while another satellite platform known as the Nigerian Communications Satellite (NigComSat) is communication-based and is of less relevance to this study. In addition to the investments made by NASRDA in the generation of satellite data, it is also imperative to dwell on the role NASRDA has played (and continues to play) in improving geoinformatics education from 2003, by making available RS data, software, training to researchers, and through the establishment of Centres of Geoinformatics in a number of Nigerian Universities, all of which would have been extremely difficult to achieve otherwise.

IT infrastructure and applications in higher education

Effectively, geoinformatics education in Nigeria's higher education institutions commenced at the postgraduate level in the 1996/97 academic session at the Department of Geography, University of Ibadan, with a pioneering enrolment of 30 graduate students, followed by the M.Sc. (Research and Professional) programs for GIS at the Department of Geography of Obafemi Awolowo University (2002–2003). Others include the University of Lagos, the Federal School of Surveying and the ECA Regional Centre for Training in Aerospace Surveys (popularly known as RECTAS) (Fadahunsi, 2010). According to Ayeni (1984), remote sensing education and application commenced in Nigeria as part of Surveying and Geography curriculum but later expanded to include disciplines such as Geology, Agronomy, Geography and Forestry. Furthermore, geoinformatics training had been conducted at three levels: firstly, at the professional training level which is carried out mainly at Universities; secondly, training for "technologists" mainly at the Polytechnics, Colleges of Technologies and the only Federal School of Surveying in Nigeria; and, thirdly for technicians who were trained either in the Polytechnics or through accumulated experience on the job (Nwilo, Peters, & Badejo, 2000).

Challenges

The major progress recorded in geoinformatics education in less than the 20 years of space technology adoption, the critical issues currently slowing the pace of expansion are the lack of adequate and up-to-date facilities/equipment, delays in upgrading training of personnel, inadequate numbers of appropriately trained teaching staff and inadequate funding to conduct applied research studies. These are some of the gaps described in the World Bank "Guidelines for Education and Training in Environmental Information Systems in Sub-Saharan Africa: Some Key Issues" of 1992. Additionally, access to satellite images from Nigeria's satellite continues to be unreliable, and hence most researchers still depend on remote sensing data from other platforms, such as Landsat, SPOT, Quickbird, IKONOS, etc., for local studies. Up-to-date software and hardware are also a major challenge as there are hardly any locally based successful software and hardware development firms given that the sector is not yet profitable.

South Africa

Geoinformatics education in South Africa has grown over the years and plays a role in academia, research, government, private sector and NGOs. A geoinformatician in South Africa is defined as someone with the skills and competencies in the science of measurement, the collection, and assessment of geographic information and the application of that information (Du Plessis & van Niekerk, 2014). This very broad definition is similar to the broad nature of GIS itself. The development of GIS in South Africa has not lagged significantly behind that of the developed countries (Hall, 1999). GIS has permeated people's lives dramatically through platforms such as Google maps, Google earth, and location-based services on mobile phones. The level of application of GIS in South Africa described as having an emergent technical and human resource infrastructure that is capable of supporting a high level of GIS use (Fleischmann & van der Westhuizen, 2017; Hall, 1999). The following discussion focuses on GIS education and training in education, the private sector, and government.

Private and government sector involvement

From a private sector perspective, the Environmental Science Research Institute (ESRI) in South Africa, the largest GIS software vendor in South Africa, also offers various short courses in GIS and in 2016, it started to offer a diploma in Geo-Information Science and Technology. ESRI is also in the process of registering a private higher education institution in different countries in Africa. The South African Qualifications Authority (SAQA) and the South African Geomatics Council (SAGC) have accredited some of ESRI's courses. There are other small players in the private sector who offer GIS courses, but prospective students need to verify whether such players are registered to offer such qualifications by the Department of Higher Education. Hence, there is a need to regulate and standardize GIS curricula. The GIS industry is growing as technology advances and there is a need to firmly regulate and standardize GIS curricula and qualification through bodies such as SAQA and SAGC.

At the state level, various government departments heavily utilize GIS and support its applications. The Department of Rural Development and Land Reform are at the forefront through the Chief Directorate: National Geospatial Information and Surveyor General as they are custodians of South Africa's geospatial data. Other governmental departments such as Agriculture, Water, and Environmental Affairs are also at the forefront of GIS use. Similarly, the South African Space Agency (SANSA) established in 2010 is also at the centre of driving applications and education of GIS. SANSA has collaborated with organizations such as the International World Bank and the Japan International Cooperation Agency to conduct training on the utility of earth observation and crop monitoring.

IT infrastructure and applications in higher education

At University level GIS qualifications have been offered as a degree or diploma since the early 1990s. In South Africa, most universities offer GIS education at all degree levels (Ntshoe, 2003; Zietsman, 2002) either as coursework or through research in departments such as geography, surveying, town planning, environmental and computer science (Musakwa, 2017). Most Universities offer GIS degrees through face to face contact sessions, for example, Stellenbosch University, whereas others are taught through distance learning such as the UNIGIS offered by the University of Pretoria and Nelson Mandela Metropolitan University (Breetzke, 2007). However, logistical challenges, high dropout rates, technical and practical problems are major impediments to the GIS courses offered through distance learning (Fleischmann, van der Westhuizen, & Cilliers, 2015; Innes, 2012).

GIS education leads to various qualifications as well as competencies. GIS professionals are supposed to be component in core areas, namely, data acquisition, IT, data analyses and photogrammetry and remote sensing (van Niekerk, 2012). Besides the core competencies, there are other competencies that are job specific, e.g. urban planning or environmental management. In South Africa, there is a broad application of GIS from traditional areas such as spatial planning, information technology, environmental planning, utilities, mining (Coetzee, Eksteen, & Roos, 2014), to emerging areas such as precision agriculture (Di Biase et al., 2010). Since the application areas for GIS are broad, the Department of Labour's Employment and Training Administration in the USA devised a geospatial applications workforce framework. This framework defines geospatial occupations framework and a competency model (Table 1).

The above framework can also be modified for South Africa, where occupations ranged from GIS Scientist, Technicians to Surveyors, which are applied in various disciplines. Though the application disciplines vary, GIS professionals are supposed to have a set of core competencies (Coetzee et al., 2014).

Challenges in GIS education

GIS education and advancement in South Africa has made significant advancements (Hall, 1999), since it is a constantly changing field, with for example, the use of drones, volunteered geographic information and big data as emerging aspects of GIS education (Musakwa, 2017). Although the level of education and infrastructure is advanced and almost comparable to the developed world there are challenges that hinder the full potential of GIS education in South Africa (Archer, 2017; Hall, 1999). These challenges are mostly to do with resources (financial, human and infrastructure) and standardization of GIS

Table 1. Geospatial occupations and competency framework.

GIS occupations	Competencies
Geospatial Information Scientists and Technologists	Management Competencies
Geographic Information Systems Technicians	Occupation-specific Requirements
Remote sensing Scientists and Technologists	Occupation-specific Technical Requirements
Remote sensing Technicians	Occupation-specific Knowledge Areas
Precision Agriculture Technicians	Industry-specific Technical Competencies
Geodetic Surveyors	Industry-wide Technical Competencies
Surveyors	Workplace Competencies
Surveying Technicians	Academic Competencies
	Personal Effectiveness Competencies

Source: U.S. Department of Labor Employment and Training Administration.

education curricula (van Niekerk, 2012). With regards to human resources, there is a limited number of qualified and accredited persons to teach GIS at a university level (Musakwa, 2017). Furthermore, the number of GIS professionals in South Africa is limited, and hence unqualified personnel occupy some jobs. This affects service delivery in the public sector. There have also been challenges with registration of GIS professionals. However, the new SAGC seeks to address this issue (Knight, 2018; Zietsman, 2002).

Tanzania

In the 1990s, Tanzania witnessed the first use of GIS by several agencies for providing support to the urban planning management process. Some organizations adopted it for spatial databases, data, input and retrieval and for data manipulation, analysis and decision-making. The sectors where GIS is currently being used in Tanzania include natural resources discovery/management, water management (irrigation and hydrology), ecological monitoring, tourism, agriculture, land information systems, demography, and analysis of census (Kundi & Ngereja, 2003).

Private and government sector involvement

Encounters that impede the development of GIS training in Tanzania are comparable to any other evolving country associated with the dearth of both material and human resources. Although GIS and ICT proficient personnel are increasing in Tertiary Education Organizations (TEOs) and across the culture in general, there are complications in integrating GIS in education. However, this is complicated by the fact that GIS philosophies and ideologies need IT infrastructures for handling, accessing, and applying the accessed information. However, the use of IT infrastructures in GIS requires an amount of computational knowledge both from geography and computer studies subjects from high school or university level of education.

On the other hand, the Tanzania Academic Institutions' attention is being drawn to matters related to the application of GIS and ICT research and instruction because social requirements are demanding urgent attention (Doherty, 1982; Mtitu, 2014; Mwita, 2013; Walshe, 2016). Although GIS and ICT knowledge is frequently accumulating at Advanced Education Institutions (AEIs) and in the public generally, institutions of higher education lack expert staff and novel research settings. With reference to Tate and Jarvis (2017), education and instruction of GIS are required to advance skills with specific GIS tools in which students need to be trained to apply in areas such as environmental science, civil engineering, and geology.

In addition, there is traditional inequality amid an increasing number of student admissions and a limited number of teaching staff. According to other published research, it is the fact that some class's enrolments are too large for the qualified teachers who do not have enough assistants to help them give lessons (Sumari, Shao, & Kira, 2017). Through enrolment, the Tanzanian Commission for Universities (TCU) have been paying attention to the process of monitoring the number of registered students and the number of teachers that have the required qualifications for ICT and GIS courses or training program across Tanzania (Tanzania Center for Science, 2014). Even though GIS in Tanzania is still nascent, there are many strategies for setting overcoming these shortfalls in resources (Kundi & Ngereja, 2003).

IT infrastructure and applications in higher education

GIS continues to play an important role in educational institutions. Most of the universities focus on teaching and training students through workshops in applying geospatial information or other related topics in this field. In 2016, Nelson Mandela African Institution of Science and Technology (NM-AIST), Arusha in collaboration with the Pennsylvania State University (Penn State) hosted a training workshop in the application of GIS, qPCR, and Microbiome Sequencing and Bioinformatic Analyses for Pathogen Discovery. Another institution is the University of Dar-es-Salaam and the University of Turku, working together in HEI-ICI project to develop higher education teaching, learning and infrastructure capacities in GIS (MFA/HEI-ICI, 2017–2019).

Several projects can be cited as good examples of GIS applications in Tanzania. Some municipalities, institutions and district councils have applied GIS in environmental management projects and through these projects, a number of users have been trained for different applications, which has improved accessing and handling of information concerning remote sensing and GIS. For Instance, in Tanzania, Figure 3, Trans-SEC conducted collaboration of institutions UHOH, PIK from Germany and SUA from Tanzania trained teachers and staff to be able to gain knowledge for the use of WebGIS for the Tanzania Food and Land Productivity Information System (TFLIS) project. Also, National ICT Policy as supported by education and training policy, information and technology present novel opportunities to support education and to improve the quality of education in different areas.

Figure 3. Trans-SEC (Innovating pro-poor strategies to safeguard food security using Technology and Knowledge Transfer) has hosted three workshops in 2014, 2015 and 2016 for TFLIS National stakeholders at Sokoine University of Agriculture (SUA), Morogoro-Tanzania.

Challenges

The most critical problems facing GIS in Tanzania is lack of suitably qualified personnel, GIS research laboratories (such as buildings and maintaining a skilled staff) and a good curriculum (with textbooks and subscriptions to journals and newsletters) for higher education. Whereas GIS is now taught in secondary education, colleges and universities in developed countries, Tanzania has only limited teaching of GIS at higher education levels. Some universities such as the University College for Architectural Studies (UCLAS) at the University of Dar es Salaam, Tanzania (UDSM) has GIS professional training in its undergraduate curriculum. Its Department of Land Surveying is the only one of the country's universities to have a full GIS teaching programme in its undergraduate degree course in land surveying. The UDSM, in its postgraduate course in computer science, has GIS as an optional subject, while geology, geography and environmental studies offer some GIS possibilities. This causes the problem of availability of qualified personnel for sustainable GIS implementation difficult to solve (Tsai & Chen, 2014).

Zimbabwe

Although Zimbabwe still lags behind other countries in GIS education and training, efforts are being made to help the country catch up with its Sub-Saharan counterparts.g The country has realized the need for improving GIS training and education at various institutions and efforts have been made to introduce educational and training courses.

Private and government sector involvement

The Scientific and Industrial Development Centre (SIRDC) through the Geo-Information and Remote Sensing Institute (GRSI) has been instrumental in providing GIS education and training in Zimbabwe (Fazekas, 2005). The GRSI focuses on the following: Natural Resources Management, Earth and Water Resources Management, and Land Administration and Facility Management. Training has also come in the form of assistance from foreign professionals. Australia, for example, has assisted local authorities to implement Geographic Information Systems (GIS). This has seen GIS training is provided for staff members in Gweru, Kadoma, Chinhoyi, and Kariba local authorities.

The government has offered its support for GIS training in institutions through the State Universities. An example is the University of Zimbabwe that in 2012, upgraded its GIS diploma course to a full-time 4-year undergraduate degree course. In addition to this, the University of Zimbabwe (UZ), which is the largest academic institution in the country, also has a geoinformatics and surveying department which was established in 1986 and offers education in geodesy, Mine Surveying, Engineering Surveying, Photogrammetry, Remote Sensing, Cartography and Geographic Information Systems. The department of Rural and Urban Planning (DRUP) at the UZ has also been offering GIS for several decades to prepare its graduates for their occupations, although the course mainly covered the basics as a single semester module during the second year. The course has however prepared several town planning graduates who have gone onto specialize in the field, taking further courses and degrees at higher levels and become experts in GIS. Other institutions of higher learning that include the Midlands State University (MSU), the Chinhoyi University of Technology (CUT), the National University of Science and

Technology (NUST) as well as the Great Zimbabwe University (GZU) have realized the importance of GIS and as such they have added the tools in several programs particularly within the faculties of natural and social sciences.

IT infrastructure and applications in higher education

At the NUST, the department of Environmental Science and Health has made great strides in infusing GIS and remote sensing within their honours degrees. GIS and RS are offered throughout the fourth year in both semesters with the first semester imparting the basics of the module whilst the second semester largely focuses on applying the knowledge and practising the use of various software. Investing in GIS and RS has given students options that they can specialize in and demonstrate their passion in areas such as GIS, which was not the case before the module was introduced and received support from the institution. GIS and RS are also being taught and practised within sister departments within the institution and these among others include civil and water engineering as well as the department of forestry and wildlife (Gumbo, Juizo, & van der Zaag, 2002).

The GZU has GIS and remote sensing infused in several degree programs thus preparing its graduates for the world of GIS applications. The GIS and RS module are offered as one of the compulsory courses in the first year of both the honours degrees in geography and environmental sciences as well as the honours degree in urban planning and development. The GIS and RS modules have given an invaluable foundation to graduates of the two programs and several have gone on to study further in the fields of GIS and RS. Within the CUT, a short learning course in GIS has been developed and is being offered mainly to practitioners specializing in natural resources management and related development programs. The course has been very useful as it has been imparting knowledge to professionals involved with the planning and management of natural resources.

Challenges and opportunities

However, in a challenging economy, Zimbabwe has been faced with high levels of brain drain. In 2006, an estimated 3 million out of 14 million Zimbabweans, the majority of whom were professionals, were living outside the country (UNDP, 2006). This number could have increased over the past 10 years as professionals continue to leave the country to avoid the economic meltdown. GIS education and training has not been spared from the effects of brain drain in the country as professionals have moved to neighbouring countries such as Namibia and South Africa. Consequently, this has left a huge gap in both GIS academic education and professional training, hence the need to introduce better ways to meet these needs.

Initiatives and concluding remarks

There are still initiatives that can be adopted from the World Bank "Guidelines for Education and Training in Environmental Information Systems in Sub-Saharan Africa: Some Key Issues" published in 1992 and incorporated by sub-Saharan Africa governments and educational institutions to improve geoinformatics education. As has been observed, it is a growing and evolving field of study, but it can be further simplified but emphasized as a crucial tool for sustainable environmental resource exploitation and management. The use of information technology in GIS in sub-Saharan Africa remains a growing field of study in education institutions and at public/government decision and policy-making agencies which should therefore continue to be strengthened with increased resources allocation and capacity development. Despite these initiatives, schools and government agencies in various countries of sub-Saharan Africa are below the required level of competence and application of GIS in the teaching-learning and application processes. The GIS facilities are lacking in schools, the capacity for using GIS by both teachers and students is yet to be optimized as a public decision-making tool. Even though there are evident benefits in the use of geo-information in schools, there are a lot of factors inhibiting the successful application of geoinformatics education, and a list of typical curricula in geoinformatics education is suggested (Du Plessis & van Niekerk, 2014; Masika & Jonas, 2016). Sub-Saharan African countries should focus on the following critical aspects to improve education and training in geoinformation such as: (i) strictly controlling the size of the classes, (ii) improving the quality of the curriculum, (iii) strengthening international and regional cooperation by means of exchange programs, (iv) improving the quality and qualifications of teachers through sustained capacity building and training programs. As clearly shown by Scott and Rajabifard (2017), many of the education and training issues affecting sustainable development in Sub-Saharan Africa can be analysed, modelled and mapped within a geographic context, thus making geo-informatics education a vital tool for the socio-economic development of the region.

Acknowledgments

The authors gratefully acknowledge the comments and suggestions made by the anonymous reviewers to help improve this manuscript. Neema Sumari gratefully acknowledges the assistance of Professor John Trinder, of the University of New South Wales, Australia, both for his English language editing of this paper, plus his valuable suggestions for improving the content of the paper, based on his vast international experience in Africa.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported in part by the National key R & D plan on strategic international scientific and technological innovation cooperation special project under Grant 2016YFE0202300, the National Natural Science Foundation of China under Grants [61671332], [41771452], and [41771454], the Natural Science Fund of Hubei Province in China under Grant [2018CFA007].

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