Tertiary education institutions in Africa: Cloudy with a chance of GISc education in some countries

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Abstract

The world is facing many global challenges: climate change, food security, sustainable development and humanitarian assistance after disasters, to name a few. For Africa with its many natural resources, fast increasing population and accelerating economic development, the need for spatial planning and management is vital. Geographic information science (GISc) knowledge and skills are required to facilitate this spatial planning and management, but does Africa have the required tertiary GISc education capacity? In this article, we present and analyse the results of a survey of just over 600 websites of African tertiary education institutions. We searched for modules and degree programmes in geographic information systems (GIS), GISc, surveying, geomatics and remote sensing. To our knowledge, a similar study has not been undertaken. The findings show a number of concerning trends on the continent. GISc is presented at very few tertiary education institutions, and where it is presented, it is often integrated as a module in a degree programme of a related discipline, such as environmental science or geology. There are degree programmes that specialise in GISc, surveying or geomatics, but we could not find any that specialise in remote sensing. The findings also show that the situation with GISc education at tertiary institutions in Africa is 'cloudy' because dysfunctional websites make it difficult to find information.

1. Introduction

The world is facing many global challenges: climate change, food security, sustainable development, and humanitarian assistance after disasters, to name a few. A number of international initiatives aim to address these challenges through geographic information and earth observation. For example, the United Nations Initiative on Global Geospatial Information Management (UN GGIM) promotes the development and use of global geographic information to address key global challenges (UN GGIM 2012). The Group on Earth Observations (GEO) aims to establish a Global Earth Observation 'system of systems' (GEOSS) that empowers the international community to protect itself against disasters and to plan for a sustainable future (GEO 2012). These initiatives confirm the need for scientists and professionals with GISc knowledge and skills.

For the future of Africa with its many natural resources, fast increasing population and accelerating economic development, this need is vital (Ikhuoria 1999, Mohamed and Plante 2002, Zietsman 2002, Williams 2008, Davies 2010). GIS technology allows different aspects of reality to be cross-referenced, making it useful for spatial analysis and planning in a wide variety of applications such as health and environmental monitoring, disaster risk reduction, land use planning

and crime analysis.

In sources from different regions in Africa, the provision of educational resources is stressed repeatedly as the necessary ingredient for building local expertise and a professional community (Ikhuoria 1999, LeDrew 2011, Okafor 2011, Tapsoba 2011). All too often foreign professionals are employed by governments, without local counterparts and without effective mechanisms for the transfer of skills and knowledge (Cavric *et al.* 2003).

In the light of the above, the objective of this first study was to identify GISc education trends at tertiary education institutions in Africa. To our knowledge a similar study has not been undertaken. In this article, we present and analyse the results of a survey of just over 600 websites of African tertiary education institutions.

The remainder of the article is structured as follows: in section 2 we explain the GISc education terminology used in this article; in section 3 we describe related work; in section 4 we describe the methodology followed to survey the websites; in section 5 we present the results of our survey and discuss them; and we conclude in section 6 with the implications of our findings for the future of Africa and possible future research.

2. GISc education and terminology

Geographic information systems (GIS) emerged in the 1960s. By the 1980s, authors wrote about 'computerised geographic information systems, also referred to as digital cartography' (Goodchild 1988, Tomlinson 1988). Early GIS products were used to capture, store, display, manipulate and analyse geographic information on desktop personal computers (PCs). A more source defines GIS as 'a computer-based system to aid in the collection, maintenance, storage, analysis, output and distribution of spatial data and information' (Bolstad 2008). Technological developments and widely available geographic information have expanded the scope and complexity of GIS. As GIS evolved, the science behind it also evolved and today GIS are one of many components of *Geographic Information Science (GISc),* a multidisciplinary research enterprise that addresses the nature of geographic information and the application of geospatial technologies to basic scientific questions. GISc is based primarily in the discipline of geography, but draws upon insights and methods from philosophy, psychology, mathematics, statistics, computer science, landscape architecture, and other fields (UCGIS 2006). The definition of geoinformatics is similar to that of GISc (Karimi 2008) and we therefore use GISc as a synonym for geoinformatics in this article.

Geomatics typically refers to the 'GIS-ification' or computerisation of surveying. For example, Gomarasca (2009), defines geomatics as the systemic, multidisciplinary, integrated approach to selecting the instruments and the appropriate techniques for collecting, storing, integrating, modelling, analyzing, retrieving at will, transforming, displaying and distributing spatially georeferenced data from different sources with well-defined accuracy characteristics, continuity and in a digital format. In our study we distinguished between GISc and geomatics degrees.

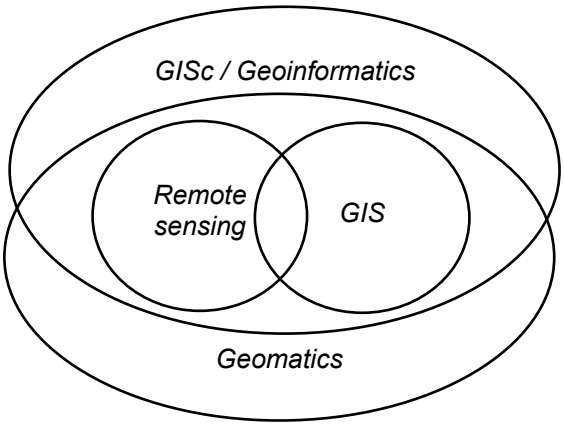


Figure 1. The relationship between GISc, geomatics and GIS

Remote sensing refers to the collection of information about an object or phenomenon without being in physical contact with it. As a result of the recent surge in availability of satellite imagery and aerial photography, remote sensing is increasingly applied and remote sensing education has received renewed attention and prominence (DST & NRF 2010).

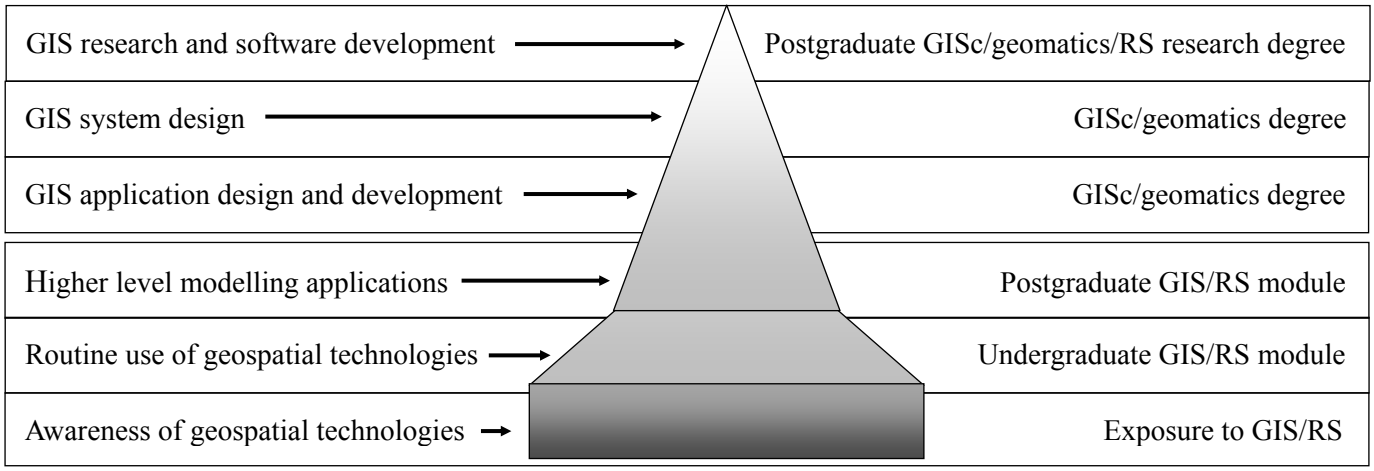
From the definitions above it is evident that there is a large overlap between geomatics and GISc and both geomatics and GISc include GIS and remote sensing. See Figure 1. In this article we use the term GISc to refer to the academic discipline and we use the term GIS to refer to the application of GIS technology as a tool.

At tertiary level, GISc and geomatics education is offered in various ways, listed below in increasing order of specialisation:

1. Exposure to GIS and remote sensing integrated into modules of undergraduate and postgraduate degrees.
2. GIS or remote sensing modules in an undergraduate degree.
3. GIS or remote sensing modules in a postgraduate degree, such as a course-based Masters.
4. GISc and geomatics degrees
5. Postgraduate GISc, geomatics or remote sensing research degrees (Honours, Masters or PhD).

In the first three cases, students learn how to use GIS and remote sensing as tools in other disciplines, such as environmental science and geology. In the last two, students are educated to be professionals and researchers in the GISc and geomatics disciplines. In this article, we use the term 'GISc education' to collectively refer to all five types of tertiary education, i.e. GIS and remote sensing modules taught in other disciplines, as well as undergraduate and postgraduate degrees in GISc and geomatics.

Marble (1998) identified a pyramid of six GISc competency levels required in industry. These can be seen as the *demand* for GISc education. In Figure 2 the levels are shown on the left hand side. We have added the corresponding GISc education levels, the *supply*, on the right hand side of Figure 2. GISc education (supply, right) should be offered to meet the required competency levels (demand, left).



Note: RS = remote sensing

Figure 2. GISc competency levels and corresponding GISc education levels

3. Related work

A 1996 survey assessed the status of digital mapping and GIS education in some developing countries of Africa, Latin America, Middle East and Eastern Europe. Most developing countries did not have higher degree training programmes in digital remote sensing and digital cartography (Ayeni 1996). A 2003 report from Botswana states that GIS is used as mapping tool instead of supporting political, economical and social decision making for sustainable development in the country. The authors identified education as one of the key areas to improve this situation (Cavric et al. 2003). In other sources from various regions in Africa, educational capacity for building local expertise and a professional community is emphasised (Ikhuoria 1999, LeDrew 2011, Okafor 2011, Tapsoba 2011).

A 2008 study describes the dire situation of Earth science education in Africa (Schlueter and Davies 2008). In classic mining countries, such as South Africa, for a population of about 48 million there are at least 13 universities with Earth science departments, ranked quite highly in international rankings. At the other end of the scale, some of the smaller countries provide no Earth science education at all. Somewhere in-between are countries with a good number of Earth science departments, sometimes with highly skilled people but poorly equipped. Political instability contributed to the deterioration of Earth science departments in others. This study is closely related to ours, since many Earth scientists make use of GIS and remote sensing. Indeed, Schlueter and Davies (2008) recommend specialisation in GIS and remote sensing to be included in tertiary Earth science curricula.

The results of the above study prompted the *Earth Science Education Initiative in Africa* of the United Nations Educational, Scientific and Cultural Organisation (UNESCO) (UNESCO 2012b). A complementary study has found, amongst others, that most authors (more than 85%) from Africa who contributed to the Journal of African Earth Sciences during the period 2000-2010 belong to only ten countries (in decreasing order): Morocco, South Africa, Egypt, Cameroun, Tunisia,

Algeria, Botswana, Tanzania, Nigeria and Ethiopia; the top four countries contributed more than 50% (UNESCO 2012a).

There are positive reports about GISc education capacity building in a number of African countries (Zietsman 2002, Schilling et al. 2005, Okafor 2011, Tapsoba 2011). Tapsoba (2011) points out that higher education in Africa is rapidly changing, showing positive trends, even though African universities are not well represented in international university rankings. Admission requirements and procedures are rigorous and African graduates win places at universities in Europe and the US.

In our home country, the South African Council for Professional and Technical Surveyors (PLATO) introduced professional registration for GISc technicians, technologists and professionals in 2004 (PLATO 2010) and professional registration is now included as a promotional criterion for government officials. This has spurred an interest from government employees to improve their GISc education to meet PLATO requirements for professional registration. PLATO's planned accreditation of selected South African degree programmes aims to standardise the level of GISc education in the country, thus contributing towards building GISc education capacity in South Africa (and Africa).

To our knowledge a survey of websites of tertiary education institutions, or other similar study, aimed at analysing GISc tertiary education capacity in Africa, has not recently been undertaken. The findings of our study are relevant to educators and researchers in Africa and beyond.

4. Methodology

Less than five African universities are listed on the better-known university rankings, such as the Times Higher Education University Rankings (THE 2012a) and the Academic Ranking of World Universities (ARWU) (ARWU 2012). We therefore used the 4 International Colleges & Universities directory (4icu.org 2012), which includes website addresses for more than 500 African universities. The 4icu.org directory includes worldwide higher education institutions that are officially recognised, licensed or accredited by national or regional bodies, are officially entitled to grant four-year undergraduate degrees and/or postgraduate degrees and provide traditional face-to-face learning facilities, programs and courses. The directory does not include two-year degree granting institutions and distance learning-only institutions. Institution profiles are included and updated free of charge and according to three unbiased and independent web metrics extracted from three different search engines. The ranking provides an approximate popularity ranking of institutions based upon the popularity of their websites. The ranking does not consider institutions or their programs by the quality of education or level of services provided.

For our study we used the 2012 list of approximately 600 website addresses from the 4icu.org directory. In a second iteration, we compared this list to close to 700 university website addresses published by Webometrics (2012), which ranks universities based on the amount and visibility of an institution's scholarly and research output on the Web. The comparison of the two lists drew our attention to the flaws of web rankings: some universities are listed twice with different names, while others are listed more than once, as university and as individual department(s). The few

additional universities that we found in the Webometrics rankings shows that the majority of tertiary institutions are included in our study. Note that we split institutions between Sudan and South Sudan, even though they are still listed for a single country on the ranking sites.

We searched each one of the university websites for modules and degrees with names that include one of the keywords shown in Table 1. Most websites were in English, others in Portuguese, French and Arabic. See Table 1. We recorded websites that did not work, for example, where links to departments or faculties did not open the appropriate page. These websites are included as 'Information not available' in our results.

Table 1. GISc-related keywords in names of modules and degrees

Language	Keywords	Websites
English	GIS, remote sensing, surveying, geomatics, geoinformatics, geographic, geographical	385
French	Les systèmes d'information géographique, informatique, télédétection, arpentage, Géoinformatique, géographique	182
*Portuguese	Sistemas de Informação Geográfica, sensoriamento remoto, levantamento, Geomatics , geográfico	3
*Arabic	نظم المعلومات الجغرافية والاستشعار عن بعد والمسح والقياس، المعلومات الجغرافية والجغرافية والجغرافية	43

* Keywords translated with Google Translate (translate.google.com)

We looked for degrees in GISc, geomatics, surveying and remote sensing, but we did not study the details of these programmes. If such a degree was found, we did not search further to establish whether some of the modules in the programme are presented to students from other disciplines. Where only individual modules in GIS or remote sensing were found (and not a degree), we recorded the highest year of study in which a module is presented and the degree in which it is presented. Our methodology does not detect exposure to GIS and remote sensing in modules where 'GIS' or 'remote sensing' does not appear in the module name. However, this exposure is negligible for our study.

We also recorded whether Masters and Doctoral studies are offered at a university. In some cases this information was obtained by implication from a staff member's list of research interests or publications. The results are therefore an estimate only. One would have to contact individual universities to get better information.

We might have missed information about GISc education, because our manual search was not good enough or because the information is not readily accessible on the university websites. The web-based rankings also imply that universities without a website, or with websites that are not automatically detected by the web rankings, are not included in the study. If we found evidence about GISc education at an institution from other sources, we corrected our results, but we know that there probably are omissions. The results of our study should therefore be interpreted as trends or indicators, rather than as actual figures. Focus should not be on whether our results show that a certain type of GISc education is offered in a particular country or not; rather, the trends or

indicators in the results of the study should be observed.

The descriptions and study guides of individual modules are typically not available or difficult to find on university websites, therefore we could evaluate neither content nor quality of the GIS education. Further, the numbers of students enrolled in modules or degrees are not readily available on websites. One would need to contact individual universities to obtain this information. Our study gathered information that can be used in a future more in-depth study.

5. Results and discussion

5.1 Websites of tertiary education institutions in Africa

Only one country in Africa does not have a single university website, namely Western Sahara. Nigeria (112) has the most, followed by Ghana (52), Algeria (49), Egypt (39), Sudan (33), Kenya (28), Morocco (27), and Uganda and South Africa (24 each). Refer to Figure 3. African universities do not feature in international university rankings: the top African university (University of Cape Town) is ranked 103rd and 201-300th in the Times Higher Education University Rankings (THE 2012b) and ARWU (2012), respectively. The top ten African universities in these rankings are dominated by South Africa, while one university in Uganda and two universities in Cairo, Egypt also appear.

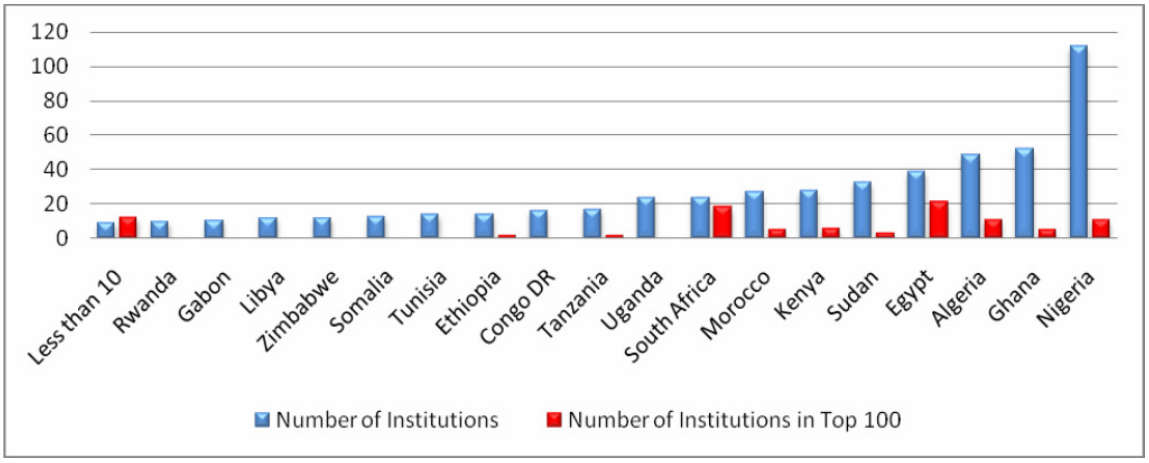


Figure 3. Number of tertiary education institutions per country in Africa

5.2 GISc education at African tertiary education institutions

Among the surveyed tertiary education institutions in Africa, we found 80 tertiary education institutions (14%) offering GISc education in some form or other. See Figure 4. A large percentage (23%) of the surveyed university websites are dysfunctional, i.e. clicking on a link to a department or faculty does not open the appropriate page. The size of a country's proportional symbol in the map in Figure 4 varies according to the number of universities offering some form of GISc education in that country as a percentage of all African tertiary institutions with some form of GISc education. Roughly, half of the countries in Africa do not have a single university presenting any of the five types of GISc education described in section 2.

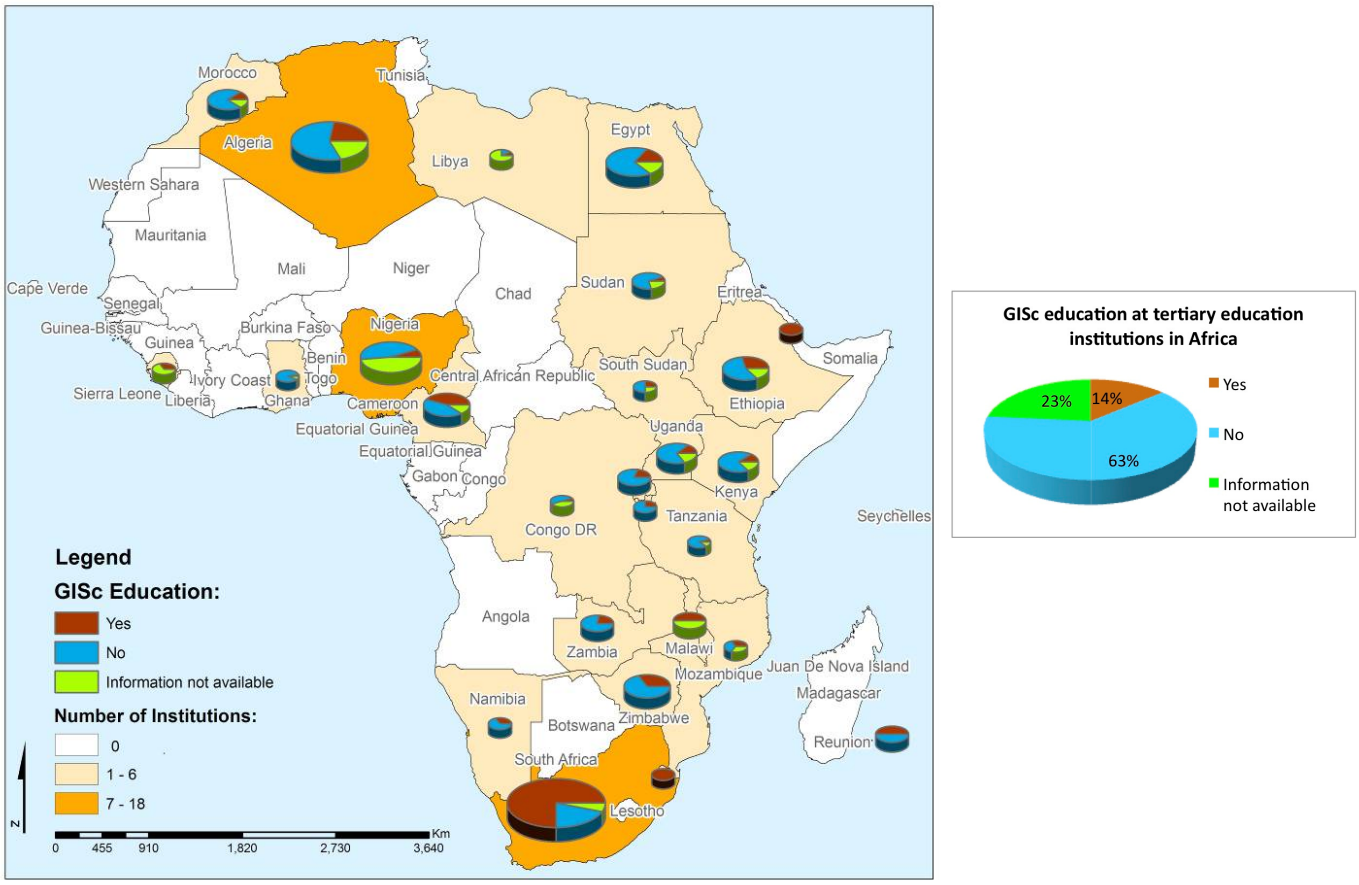


Figure 4. Tertiary institutions in Africa presenting some form of GISc education

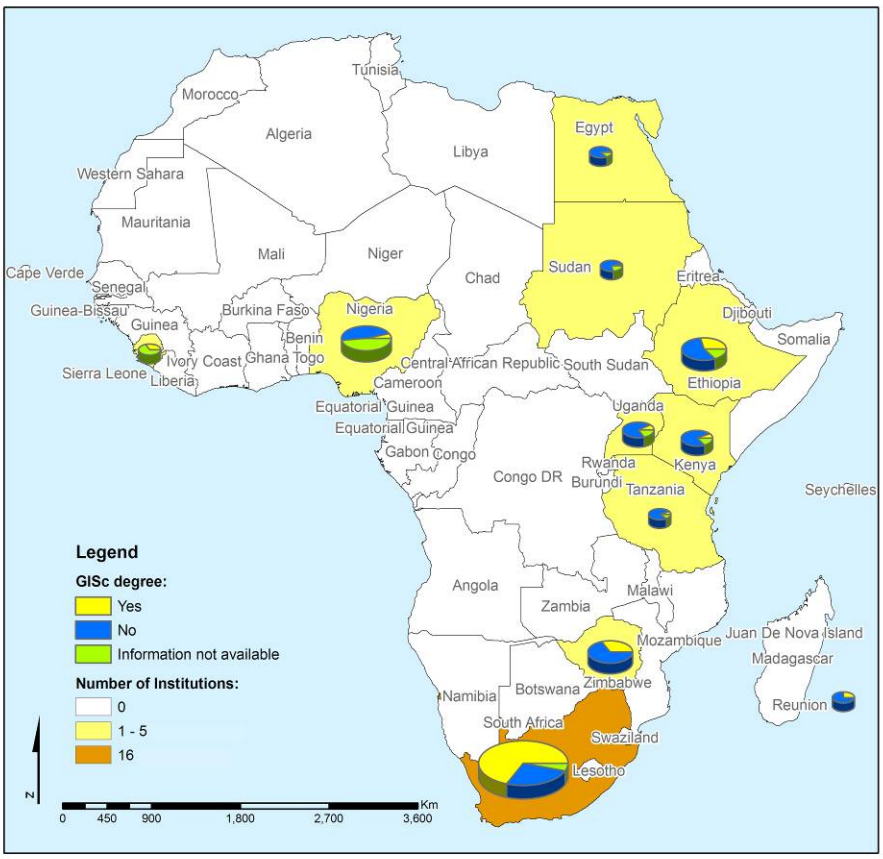
Table 2 provides an overview of the types of GISc education (described in section 2) at tertiary institutions in Africa. Roughly, half of any form of undergraduate GISc education is offered at one of the top 100 tertiary education institutions in Africa. In comparison, postgraduate research degrees are more often presented by one of the top 100 African institutions on the Webometrics (2012) rankings. Most institutions offering research degrees at Masters level, also offer them at PhD level.

The size of a country's proportional symbol on the map in Figure 5 varies according to the number of universities offering a GISc degree in that country as a percentage of all institutions offering a GISc degree in Africa. Africa's GISc degrees are presented in eleven of its 54 countries. Even fewer countries have institutions presenting geomatics degrees. The majority of African countries offer neither a GISc nor a geomatics degree. The lack of GIS modules in surveying degree programmes is a cause of concern and suggests that African degrees in surveying may be outdated.

Table 2. Overview of GISc education at African tertiary institutions

	Number of institutions	Top 100 institutions
Modules in undergraduate degrees from other disciplines		
GIS	58	25
Geomatics	0	0
Remote sensing (see Figure 6)	42	23
Modules in postgraduate degrees from other disciplines		
GIS	40	22
Geomatics	4	2
Remote sensing (see Figure 6)	18 (13 unconfirmed*)	10 (7 unconfirmed*)
Undergraduate degrees		
GISc (see Figure 5)	38	20
Geomatics	8	4
Remote sensing (see Figure 6)	0	0
Postgraduate research degrees (Honours, Masters or PhD)		
GISc	22 (11 unconfirmed*)	16
Geomatics	4	8 (2 unconfirmed*)
Remote sensing (see Figure 6)	22	8

* Indicates we could not find information on the website to confirm whether or not postgraduate studies are presented.



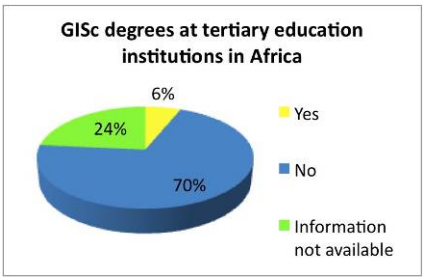


Figure 5. GISc degrees at tertiary education institutions in Africa

Figure 6 shows the distribution of tertiary institutions presenting a remote sensing module in any degree, including GISc and geomatics degrees. We could not find a single undergraduate remote sensing degree on the whole continent. Less than a third of the African countries offer some form of remote sensing tertiary education.

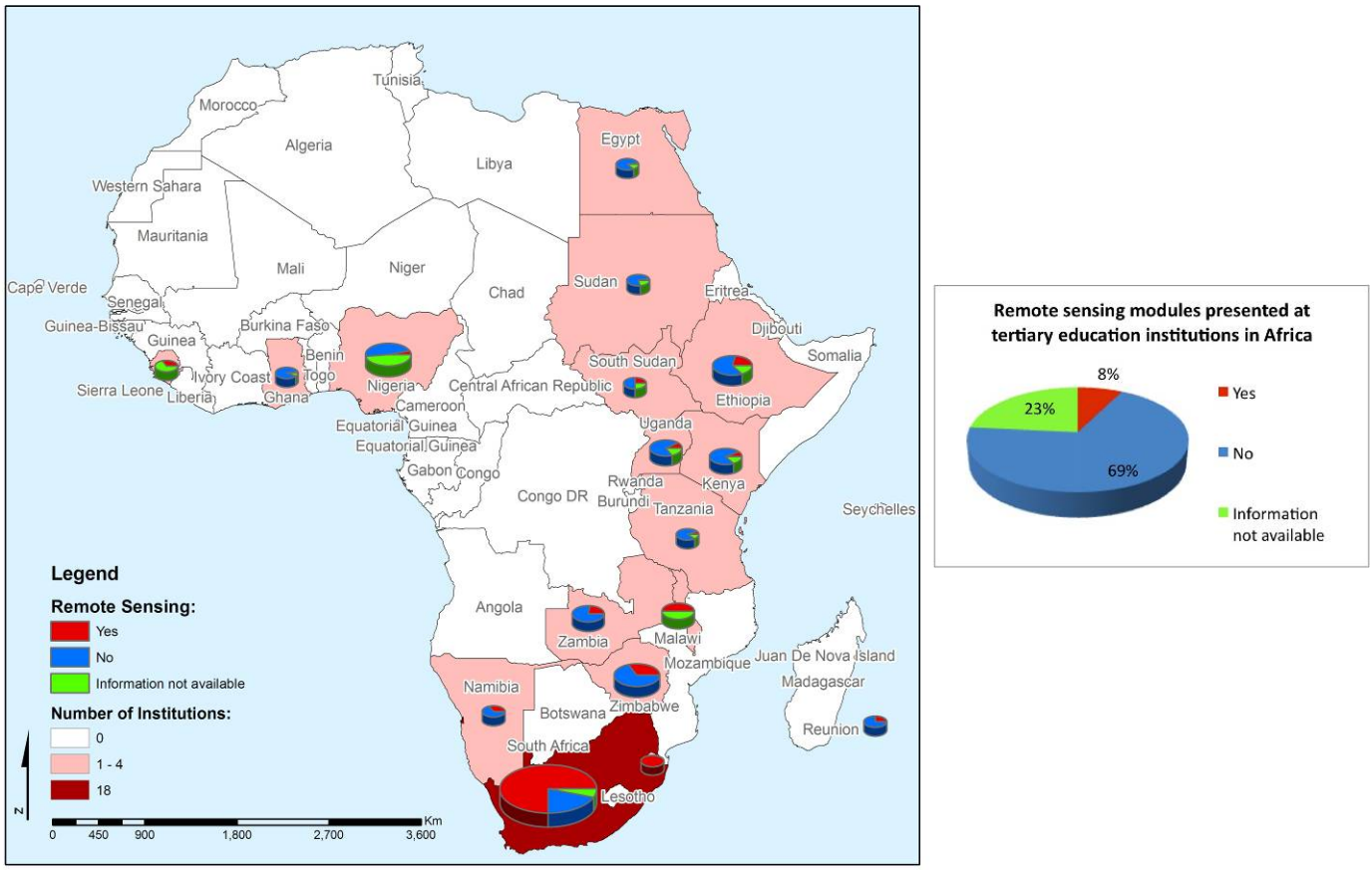


Figure 6. Remote sensing modules presented at tertiary education institutions in Africa

Figure 7 shows the education level pyramid for GIS modules, as well as undergraduate and postgraduate GISc degrees, at tertiary institutions in Africa. The width of the pyramid corresponds to the number of institutions offering the type of GISc education at the relevant level. In contrast to Marble's pyramid on the right, the African pyramid is 'flatter', either indicating that the postgraduate research offering is too big in comparison to the base, or, more likely, that the base is not wide enough.

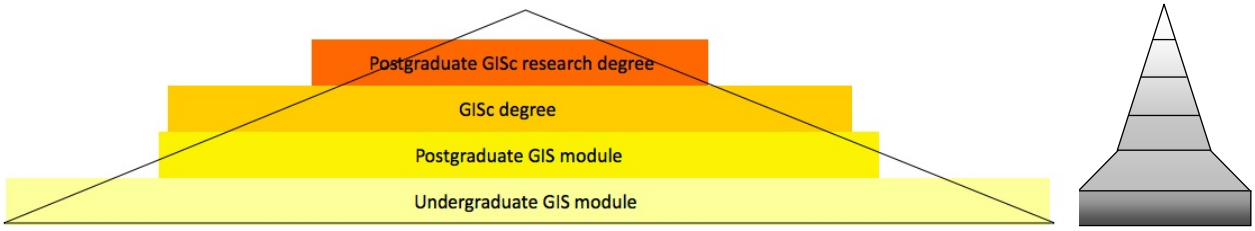


Figure 7. Education levels for GIS modules, undergraduate and postgraduate GISc and geomatics degrees at African tertiary institutions

In contrast to the pyramid in Figure 7, the remote sensing education levels for tertiary institutions in Africa in Figure 8 do not form a pyramid. The lack of remote sensing degrees and the postgraduate remote sensing research degree offering being bigger than the second base shows that the demand for remote sensing education differs from that for GISc education: remote sensing is mostly applied as tool in postgraduate research, it is not (yet) regarded as a discipline on its own at African tertiary education institutions and the need for its routine use in off-the-shelf applications is limited.

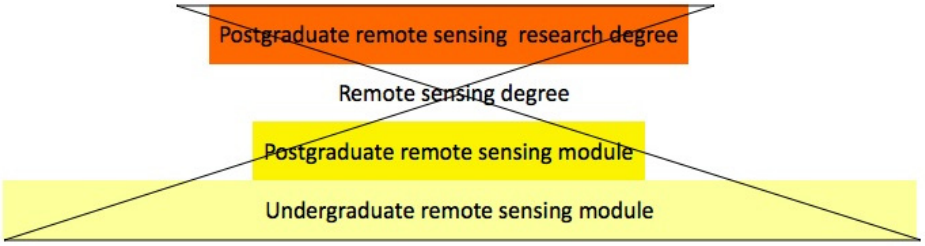


Figure 8. Remote sensing education levels at African tertiary institutions

5.3 Discussion of the results

The results of our study show a number of worrying trends. Africa has an estimated population of one billion (UN Statistics Division 2012), distributed over 54 independent countries and six other territories. Our study shows that there is less than one tertiary institution with GISc education per 10 million people. In comparison, Schlueter and Davies (2008) estimated roughly one Earth science department per 10 million people.

The maps in this article show that South Africa leads GISc education on the African content. South Africa has an estimated population of 50 million and 18 institutions presenting GISc education, corresponding to one institution for every 2.7 million people. If this is arbitrarily used as a measuring stick for the rest of the African continent, another 276 institutions with GISc education (360 in total) are required in the rest of Africa to match South Africa's institution 'density'. The U.S. Department of Labor Employment and Training Administration (DOLETA) predicts that the U.S. economy will need to add more than 72,000 additional GIS technicians, and nearly 340,000 geospatial workers overall, between 2008 and 2018 (DiBiase 2010). For Africa, more research is needed to better understand the demand for different levels of GISc education in its different regions.

The large number of tertiary education institutions offering GIS and remote sensing modules in other undergraduate and postgraduate degree programmes confirms the wide use of GIS and remote sensing as tools in other disciplines. The large number of countries without any tertiary education in remote sensing is a concern. The maps further show that many countries do not offer GISc education at higher levels of specialisation, resulting in more than half of the countries in Africa relying on other countries to educate staff for their mapping agencies. This explains the poor availability of large-scale topographic data for many African countries.

The suggestions by Schlueter and Davies (2008) for improving Earth science education capacity

in Africa, such as initiatives to increase the number of home-grown PhDs, establishing regional networks and modernising curricula, also apply for GISc education. Since GIS and remote sensing are used as tools in other disciplines, inter-disciplinary collaboration should be encouraged.

There are attractive scholarships from Europe and the US, especially on postgraduate level, for example, enabling students to complete a Masters degree without having to pay any tuition fees. These opportunities increase the continent's GISc education capacity. However, the sad truth is that not all students return to their home countries after completing their studies abroad. Distance-learning programmes, such as those offered by UNIGIS (2012) and the University of South Africa (UNISA), also increase Africa's GISc education capacity, despite their drawbacks (Breetzke 2007).

6. Conclusions

Our findings show that GISc education at tertiary institutions in Africa is 'cloudy with a chance of GISc education in some countries'. 'Cloudy' because dysfunctional websites make it difficult to find information, and chances of finding an undergraduate GISc degree on the functional websites are slim. This suggests that Africa does not have the tertiary GISc education capacity to meet its current and future challenges. Distance-learning programmes and overseas scholarships were not included in our study and extend the continent's GISc education capacity, but have their drawbacks. The findings also show that university websites do not always work, are difficult to navigate, and to find information about specific degrees and modules can be a challenge. For the future of Africa it is essential that tertiary GISc education capacity be increased within Africa.

More research is needed to better understand the demand for different levels of GISc education in different regions of Africa. For example, how many students should be enrolled in different GISc education programmes in Africa to ensure sufficient future GISc capacity, while at the same time avoiding flooding the market? And, how steep should the angle of the pyramid be, i.e. how much research in relation to undergraduate GISc education constitutes a good balance?

We have started a more in-depth study of GISc education at South African universities. Further studies could also evaluate the content, quality and capacity of the GISc education at these institutions and an analysis of where and how often African GISc scientists publish in peer-reviewed journals would give an idea of postgraduate research capacity.

African universities do not feature on international ranking lists. This implies that universities cannot compare themselves to other universities and cannot work towards improving their ranking. A ranking of African universities based on an independent and transparent survey will boost competition among African universities and assist in elevating them into international university rankings. Similarly, a ranking, or at least a transparent and independent comparison of the content, quality and student numbers, of GISc education at African universities, will have a positive effect on GISc education capacity building.

7. Acknowledgements

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8. References

4InternationalColleges&Universities directory (4icu.org) 2012, viewed 19 April 2012, <www.4icu.org>.

Academic Ranking of World Universities (ARWU) 2012, viewed 19 April 2012, <www.arwu.com>.

Ayeni, OO 1996, 'Digital mapping and GIS education in developing countries', *International Archives of Photogrammetry and Remote Sensing,* Vol. XXXI, Part B6, Vienna, Austria.

Bolstad, P 2008. *GIS Fundamentals – A first text on geographic information systems*, Eider Press, Minnesota, USA: ISBN 978-0-0717647-2-9.

Breetzke, GD 2007, 'A critique of distance learning as an educational tool for GIS in South Africa', *Journal of Geography in Higher Education*, **31**(1), pp. 197-209.

Cavric, BI, Nedovic-Budic, Z and Ikgopoleng, HG 2003, 'Diffusion of GIS technology in Botswana: Process and determinants', *International Development Planning Review (IDPR)*, **25**(2), pp.195-219.

Davies, TC 2010, 'Geoscientific environmental health issues in Africa', *International Geology Review*, **52**(7-8), pp. 873-897.

Department of Science and Technology (DST) & National Research Foundation (NRF) 2010, 'Audit of space applications training in South Africa'.

DiBiase, D et al. 2010, 'The new geospatial technology competency model: Bringing workforce needs into focus', *URISA Journal*, **22**(2), pp. 55-72.

Group on Earth Observations (GEO) 2012, viewed 19 April 2012, <www.earthobservations.org>.

Gomarasca, MA 2009, *Basics of Geomatics*. Springer: ISBN 978-1-4020-9013-4.

Goodchild, MF 1988, 'Stepping Over The Line: Technological Constraints And the New Cartography', *Cartography and Geographic information Science*, **15**(3), pp. 311-219.

Ikhuoria, IA 1999, 'Professionalism and manpower issues in geographical information systems in West Africa', *Transactions in GIS*, **3**(4), pp. 343-358.

Karimi, HA 2008, *Handbook of research on Geoinformatics*. Information Science Reference, Hershey, New York, USA, ISBN-13: 978-1591-4-0995-3.

LeDrew, E 2011, '*Report of the IEEE International Expert Panel: Recommendations for Human Capital Development for Earth Observation Programs within the Republic of South Africa'*, jointly published by the Department of Science and Technology, IEEE and the South African National Research Foundation, 7 February 2011.

Marble, DF 1998, 'Rebuilding the top of the pyramid', *ArcNews*, **20**(1), pp. 28-29.

Mohamed, M and Plante, R 2002, 'Remote sensing and geographic information systems (GIS) for developing countries', *IEEE International Geoscience and Remote Sensing Symposium (IGARSS '02)*, pp. 2285-2287.

Okafor, UGO 2011, '*Country Report on the development and innovations of the Namibian National Geospatial Information System'*, High Level Forum on Global Geospatial Information Management, Seoul, Republic of Korea, 24-26 October 2011, pp. 1-10.

Schilling, M, Twarabmeneye, E and De Vries W 2005, 'Geo-ICT capacity building in Rwanda', *GIM International*, **19**(6).

Schlueter, T and Davies, TC 2008, 'What future for geo-education in Africa?' *A World of SCIENCE*, **6**(2), pp.

2-8.

South African Council for Professional and Technical Surveyors (PLATO) 2010, 'PLATO re-opens grandfather clause', *PositionIT,* Jan/Feb 2010, EE Publishers, Muldersdrift, South Africa.

Tapsoba, S 2011, *Africa's scramble for regeneration*, viewed 19 April 2012, <http://www.timeshighereducation.co.uk/world-university-rankings/2011-2012/analysis-Africas-scramble-for-regeneration.html>.

Times Higher Education University Rankings 2012a, viewed 19 April 2012, <http://www.timeshighereducation.co.uk/world-university-rankings/>.

Times Higher Education University Rankings 2012b, *2010-2011 Rankings for Africa*, viewed 19 April 2012, <http://www.timeshighereducation.co.uk/world-university-rankings/2010-2011/africa.html>.

Tomlinson, RF 1988, The impact of the transition from analogue to digital cartographic representation. *Cartography and Geographic information Science*, **15**(3), pp249–262.

UNIGIS website 2012, viewed 19 April 2012, <http://www.unigis.net/>.

United Nations Education, Scientific and Cultural Organisation (UNESCO) 2012a, *A Study Report on the Performance of African Earth Scientists in the Journal of African Earth Sciences (JAES) during the Period 2000-2010* (KE/2011/SC/PI/1). Commissioned by the UNESCO Nairobi Office, viewed 19 April 2012, unesdoc.unesco.org/images/0021/002148/214888e.pdf.

United Nations Education, Scientific and Cultural Organisation (UNESCO) website 2012b, *Earth Science Education Initiative for Africa*, viewed 19 April 2012, <http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/capacity-building/earthscienceeducation/>.

United Nations Global Geospatial Information Management (UN GGIM) website 2012, viewed 19 April 2012, <http://ggim.un.org>.

United Nations Statistics Division 2012, *Population and Vital Statistics Report*, Statistical Papers, Series A Vol. LXIV, 1 January 2012, Department of Economic and Social Affairs, United Nations Statistics Division, New York, USA, viewed 19 April 2012, <http://unstats.un.org/unsd/demographic/products/vitstats/>.

University Consortium for Geographic Information Science (UCGIS) 2006, *Geographic Information Science and Technology Body of Knowledge 2006.* UCGIS, USA.

Webometrics 2012, viewed 19 April 2012, <http://www.webometrics.info>.

Williams, JJ 2008, 'The significance of geographical information systems for development planning', *Development Southern Africa*, **16**(2), pp. 345-356.

Zietsman, HL 2002, 'Geographic information science in South Africa', *South African Geographical Journal*, **84**(1), pp. 30-37.