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Sustainable Development: The Contribution from GISc Education in South Africa

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Abstract

Concerns over the negative impact of the deteriorating environment and declining natural resources on economic and social development prompted the drive towards sustainable development, i.e. development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Economic growth, environmental balance, social inclusion and culture have been identified as the four dimensions of sustainable development. These dimensions and their interactions are inherently spatial. Geographic information science (GISc) and geographic information systems (GIS) provide the theoretical foundation and applied technology to support planning and decision-making for sustainable development. GISc professionals are required to realize South Africa's sustainability goals put forth by the National Planning Commission. In this paper we investigate the current state of GISc education at universities in South Africa to determine whether GISc is included in relevant disciplines for sustainable development. Individual university websites and yearbooks were downloaded and analyzed. Degree programmes were categorized according to a list of prominent GISc application fields. The analysis revealed that GISc is widely included in South African tertiary degree programmes related to the environmental balance dimension of sustainable development, but not in degree programmes related to the other three dimensions, namely economic growth, social inclusion and culture.

1. Introduction

Sustainable development is a concept developed in the 1980s and plays an important role in almost any developmental aspect of any country in the world (Pezzey, 1992, Berke & Conroy, 2000). Concerns over the negative impact of the deteriorating environment and declining natural resources on economic and social development prompted the drive towards sustainable development, i.e. development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Economic growth, environmental balance, social inclusion and culture have been identified as the four dimensions of sustainable development (Agenda 21, 2013). These dimensions and their interactions are inherently spatial. For example, the relationship between humans and the environment cannot be represented without reference to a specific location; natural resources occur in specific locations; and the environment itself is described by the spatial relationships between physical objects (Campagna, 2006). Geography, geographic information science (GISc) and geographic information system (GIS), amongst others,

provide the theoretical foundation and applied technology to support planning and decision-making for sustainable development.

A number of international initiatives aim to address global challenges, including sustainable development, 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). South Africa faces challenges similar to the rest of the world. The National Planning Commission (NPC) has developed a long-term vision and strategic plan for South Africa, which includes environmental sustainability and resilience as objectives (NPD 2030, 2013).

GIS has emerged as a valuable analysis or management tool in many industries concerned with sustainable development like geography, urban planning, forestry and wildlife management, to name a few (Hyman et al, 2000; Skidmore et al, 1997; Foody, 2003; Bolstad, 2008). The successful implementation of GISc and GIS for sustainable development in government and business requires personnel with a sound theoretical foundation in GISc who are well-trained in GIS skills and technology. The results of an earlier study indicate that GISc education capacity at African tertiary education institutions is a cause for concern, but that South Africa is leading the African continent (Coetzee & Eksteen, 2012).

Students enrolling for GISc, geography or geography related programmes are exposed to GIS and have the opportunity to explore the subject matter in depth (Marais, 2008). However, the question remains if this opportunity is being extended to other disciplines in the academic world and to what extent other disciplines are exposed to GIS (Brickley & Micken, 2007). According to research done by Marais (2008), Brickley & Micken (2007) and Shepard (2009) the current trend is that students enrolled in disciplines not directly related to geography, but who have to work with spatially referenced data after graduation, are not adequately exposed to GIS as a decision making and analysis tool during their tertiary education. We analysed the current offerings of GISc education at South African universities, as well as recent Masters dissertations and PhD theses produced at these universities, to find out how widely GISc is included in tertiary education not directly related to geography, but relevant to sustainable development.

The subsequent sections are structured as follows: in the second section we summarize the important role of GISc for sustainable development. The methodology and definitions are described in the third section. In the fourth section we present the analysis of GISc tertiary education in South Africa. In the fifth section we evaluate the availability of GISc in degree programmes relating to the

four dimensions of sustainable development. We conclude and discuss possible future research in the sixth section.

2. The Role of GISc in Sustainable Development

Sustainable development is a concept that was widely published by the World Conservation Strategy in the 1980s (IUCN, 1980 in Pezzey 1992). It plays a central role when planning for environmental and developmental issues in any country (Pezzey, 1992). Although there have been various attempts since the 1980s to define the term sustainable development (Brown et al, 1987; Barbier, 1987; Goodland et al, 1987), the definition by the Brundtland (1987) report is most widely accepted (Pezzy 1992). This report defines sustainable development as 'development that meets the needs of present generations without compromising the ability of future generations to meet their own needs' (Brundtland, 1987). Sustainable development introduces a process to conserve natural resources from being overused by joining together the environment, economy and society in such a way that that it will improve the quality of life over time (ASCE, 1998). In 2010, the United Nations added culture as one of the dimensions of sustainable development (Policy statement, 2010). Sustainable development is also seen as an ongoing process without fixed goals or specific means of achieving any goals (Mitroff, 1993). Sustainable development is therefore not a means to an end but an ongoing process that needs to be managed and maintained (Berke & Conroy, 1992 , Kondyli, 2010).

Many articles have been published regarding the indicators used for the measurement of sustainable development. (Quental at el, 2011, Steurer & Hametner, 2010, Mogensen & Schnack, 2010) These indicators depend on the application field but may include variables such as changes in land use, vegetation clearing and recovery plans to name a few (ANZECC, 2000). The indicators for sustainable development are variables that play a role in the evaluations of a phenomenon contributing towards sustainable development (Tanguay et al, 2010). These indicators assist policy makers to identify appropriate policies, monitor interventions, provide information on complex phenomena and allow for comparisons over time and space (Kelly 1998). All indicators have a strong spatial component and one can conclude that GISc and GIS plays an important role towards managing and implementing sustainable development.

GISc has been proven to offer theories, methods and applications to effectively support planning and decision-making for sustainable development through the production and maintenance of geographic information, distributed access to spatial environmental information, solving spatial sustainability problems, collaborative spatial decision-making and public participation (Campagna 2006). Enemark and Williamson (2004) describe the fundamental role of a specific kind of geographic information system, namely a land administration system, in sustainable development. These systems are key to administering the relationship of people to land and are used for the administration of land as a natural resource to ensure its sustainable development. There is ample evidence in scientific literature about the use and application of GISc and GIS for sustainable

development. These articles emphasize the important role of GISc and GIS in managing sustainable development. Examples include the use of remote sensing to monitor tropical forest environments for sustainable development (Foody 2003), the use of remote sensing and GIS for sustainable land management (Skidmore et al, 1997) and in the monitoring and evaluation of rapid urban growth in the Pearl river delta in China (Yeh & Li, 1997). Hyman et al (2000) applied GIS for sustainable development at a local scale at various sites in Latin America while van Hoesen & Letendre (2010) used a GIS based approach to support a rural community to evaluate potential renewable energy sources.

In South Africa the National Planning commission (NPC) is a government initiative responsible for developing a long-term vision and strategic plan for South Africa. Some of the long term goals of the NPC is to achieve sustainable economic growth, reduce poverty and improve the quality of life of all citizens. In order to achieve these goals a National Development Plan was compiled and published in August 2012 (NPC, 2013). The objectives and actions of the National Development plan are, amongst others, to increase economic growth and decrease unemployment to 6%, to maximize the economic infrastructure by making sure that people have access to the electricity grid, access to clean water, adequate public transport and widely available and affordable internet broadband. The objectives also aim to achieve environmental sustainability and resilience, the development of rural economies, the transforming of human settlements, to provide health care to all, and the building of safer communities for all (NDP 2030, 2013).

All the above mentioned actions and objectives of the NPC have a strong spatial component and can be managed and implemented by applying GISc and GIS technologies. As indicated by Bolstad (2008), one of the most important components for the successful implementation of a GIS is human resources. One may rightfully ask the question if South Africa has enough GISc professionals to assist in implementing and managing such diverse development goals and actions, and if not, whether tertiary GISc education is available to improve the situation.

3. Methodology and Definitions

The list of 23 South African universities registered with the Department of Higher Education and Training of South Africa was obtained from their website (DOHE, 2012). We searched the websites for GISc, geographical information systems (GIS), geomatics and remote sensing degrees. We also identified other degree programmes at these universities that include GISc, GIS, remote sensing and geomatics in their curricula. The yearbooks and/or prospectuses of each university were also downloaded and searched. We searched in the SciVerse Scopus, and Nexus databases with keywords, such as ‘geoinformation science’, ‘geographical information science’ geographical information systems, ‘geomatics’ and ‘remote sensing’. SciVerse Scopus is an abstract and citation database of peer-reviewed literature. It contains 47 million records from 18,500 peer-reviewed journals, dating back as far as 1823 (SciVerse Scopus, 2012). Nexus contains the titles and abstracts of completed and current Masters dissertations and PhD theses since 1919. The full text of a limited

number of these is available (Nexus, 2013). For details of the searches, refer to Eksteen *et al.* (2012).

We broadly follow the definitions provided by the University Consortium for GISc (UCGIS, 2006) for *GISc*, ('a multidisciplinary research enterprise that addresses the nature of geographic information and the application of geospatial technologies to basic scientific questions'), *geospatial technology* ('specialized set of information technologies that handle georeferenced data') and *applications* ('the increasingly diverse uses of geospatial technology in government, industry, and academia'). We use GISc as a synonym for geoinformatics, GIS for geospatial technology, and application fields for applications. Geomatics refers to the computerisation of surveying (Coetzee & Eksteen, 2012), while remote sensing refers to the collection of information without being physically in contact with the object or phenomena.

We use the term 'tertiary education institutions' to refer to universities, universities of technology, colleges and polytechnics collectively. In the South African context 'universities' refer to universities and universities of technology registered with the Department of Higher Education. We use the term 'educational programme' as defined by the Department of Higher Education and Training: 'a purposeful and structured set of learning experiences that leads to a qualification' (Higher Education Act, 1997). Degree programme is used to denote an educational programme that leads to a degree qualification.

4. Results and Discussion

In this section we discuss and conclude on the findings of the study in terms of GISc education in South Africa and the inclusion of GISc in programmes for sustainable development.

4.1 GISc tertiary education in South Africa

The universities in South Africa have a highly unequal geographic distribution among the nine provinces. Table 1 shows the number of universities per province. The Department of Higher Education and Training has recognized the unequal distribution and two new universities are expected to open in Mpumalanga and Northern Cape in less than two years (Sowetan, 2012).

Table 1. Number of universities per province

Province (count)	Name of university
Eastern Cape (4)	Nelson Mandela Metropolitan University Rhodes University University of Fort Hare Walter Sisulu University of Technology
Free State (2)	Central University of Technology University of the Free State
Gauteng (6)	Tshwane University of Technology University of Johannesburg University of Pretoria University of South Africa University of the Witwatersrand Vaal University of Technology
KwaZulu-Natal (4)	Durban University of Technology Mangosuthu University of Technology University of KwaZulu-Natal University of Zululand
Limpopo (2)	University of Limpopo University of Venda
Mpumalanga (0)	-
North West (1)	North West University
Northern Cape (0)	-
Western Cape (4)	Cape Peninsula University of Technology University of Cape Town University of Stellenbosch University of the Western Cape
Total (23)	

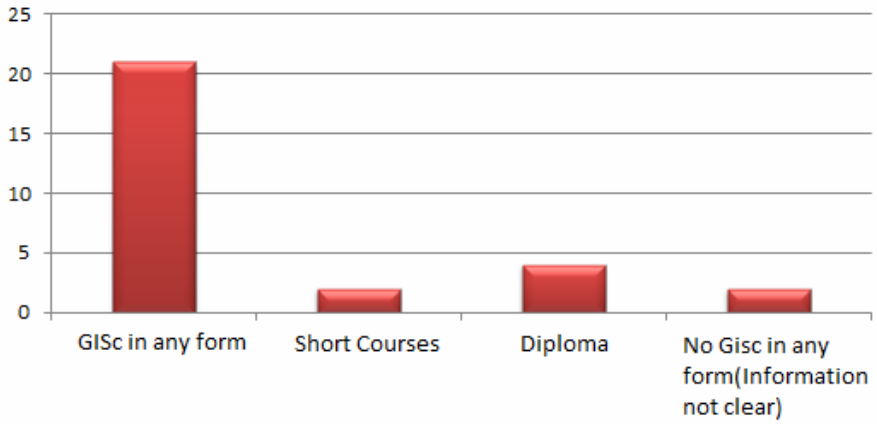

Figure 1. GISc education offerings at South African universities

GISc education is offered at 21 of the 23 universities. The information on the websites of the other two universities was unclear on whether GISc is offered and in which form. Fig. 1 shows the number of unversities and the type of GISc education offerings (including GIS, geomatics and remote sensing). Diploma studies in GISc are offered by four of the six universities of technology.

The high number of universities offering GISc education in some form is a positive sign and provides an opportunity for current students to obtain GISc knowledge. However, this GISc education is not accessible to those who already work full-time in the industry. This challenge can be addressed by short courses, certificate courses, diplomas and degrees offered part-time and/or online over the web. Only two universities offer short courses in GISc and GIS, but the numbers may be higher as courses are sometimes advertised on the websites only for a short period before they are offered, or alternatively advertised through other media.

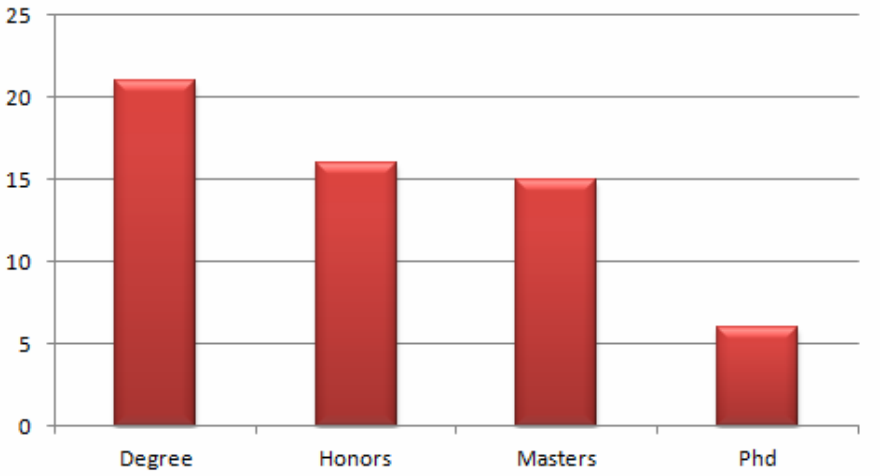

Figure 2. GISc, geomatics and remote sensing programmes at South African universities as degree or an elective

The presentation of GISc, remote sensing and geomatics on various programme levels is summarized in Fig. 2. The offering of GISc as an elective is readily available on undergraduate level. However, GISc degrees are only offered at five of the 23 universities. No university in South Africa offers remote sensing as an undergraduate degree. This confirms the finding by Coetzee and Eksteen (2012) that remote sensing is not recognized as a discipline on its own.

GISc, geomatics and remote sensing are offered as elective modules in more than 200 tertiary educational programmes at South African universities. but there are only two universities offering geomatics as an elective or degree. The low number of universities offering geomatics both as a degree and as an elective is worrisome and follows the same pattern of decline in surveying programmes observed in the rest of Africa (Coetzee & Eksteen, 2012). The question whether surveying programs are outdated is also applicable to South African universities and needs further investigation. For details on the offering of GISc as a degree and elective module refer to Eksteen *et al.* (2012).

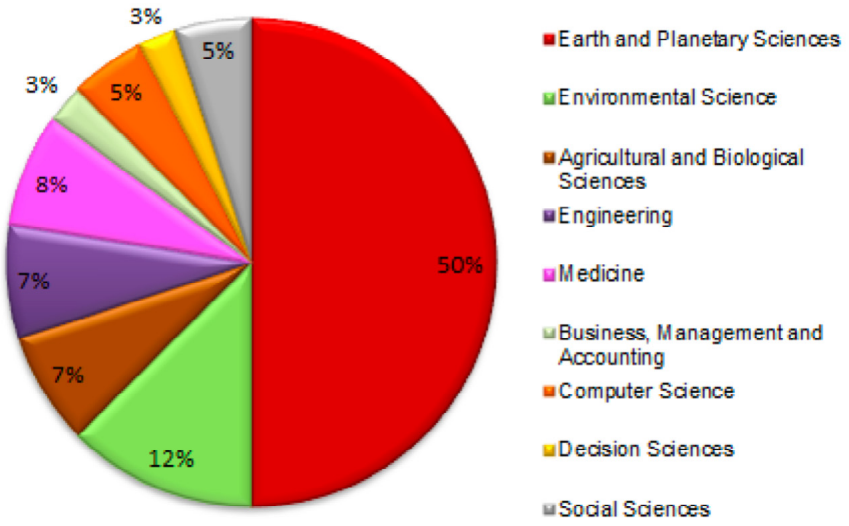

Figure 3. GISc application fields of MSc and PhD students in South Africa in the last four years (2008 - 2011)

Less than 50 of the abstracts of Masters dissertations and PhD theses produced at South African universities in the last four years have a GIS-related keyword in their abstract. Figure 3 shows the application fields of the dissertations and theses with a GIS-related keyword. Earth and planetary sciences (50%) dominate, followed by environmental science (12%), medicine (8%), agricultural and biological sciences and engineering (7% each). The rest of the application fields are at 5% or less. The low variation in the number of application fields is worrisome and needs further investigation.

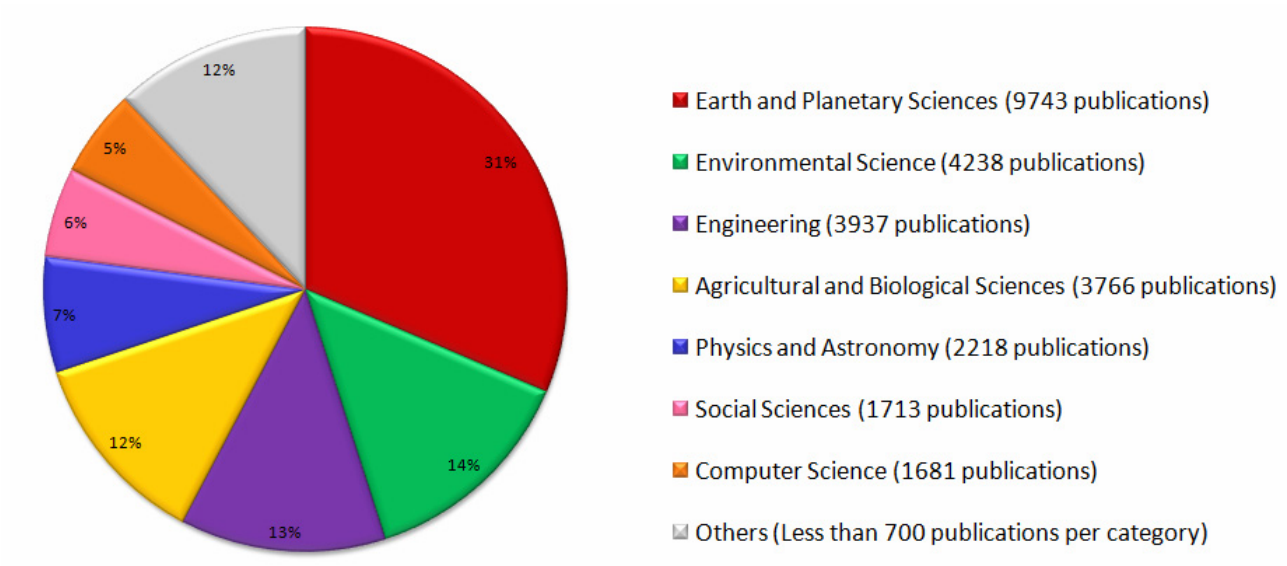

Figure 4. Prominent GISc application fields in international research publications of the last four years (2008-2011)

The search of the publications in peer reviewed journals of the past four years has indicated a total of just more than 31 000 publications with a GIS-related keyword The earth and planetary

sciences (31%) also dominate international research publications of the last four years; publications in geomorphology, geoinformatics, meteorology, remote sensing, social geosciences, geography, geology, geochemistry, petrology, geobiology, seismology and planetary studies are included here. Next are environmental science (13%), engineering (13%), agricultural and biological sciences (12%), physics and astronomy (7%), followed by social sciences and computer science with 5% each. The rest (12%) is made up of application fields like chemistry, material sciences, mathematics, biosciences, economics and veterinary sciences. Publications in the latter constituted less than 5% per application field.

4.2 . GISc tertiary education for sustainable development

GISc has been proven to offer theories, methods and applications to effectively support planning and decision-making for sustainable development through the production and maintenance of geographic information, distributed access to spatial environmental information, solving spatial sustainability problems, collaborative spatial decision-making and public participation (Campagna 2006). Sustainable development is a multi-disciplinary endeavour and GISc education should ideally be included in tertiary education programmes of relevant disciplines.

In this section we analyse the inclusion of GISc in degree programmes related to the four dimensions of sustainable development. For this, South African degree programmes with GISc, geomatics and remote sensing as electives were categorized according to the list of GISc application fields identified in international research publications of the last four years. The summary is shown in Figure 5.

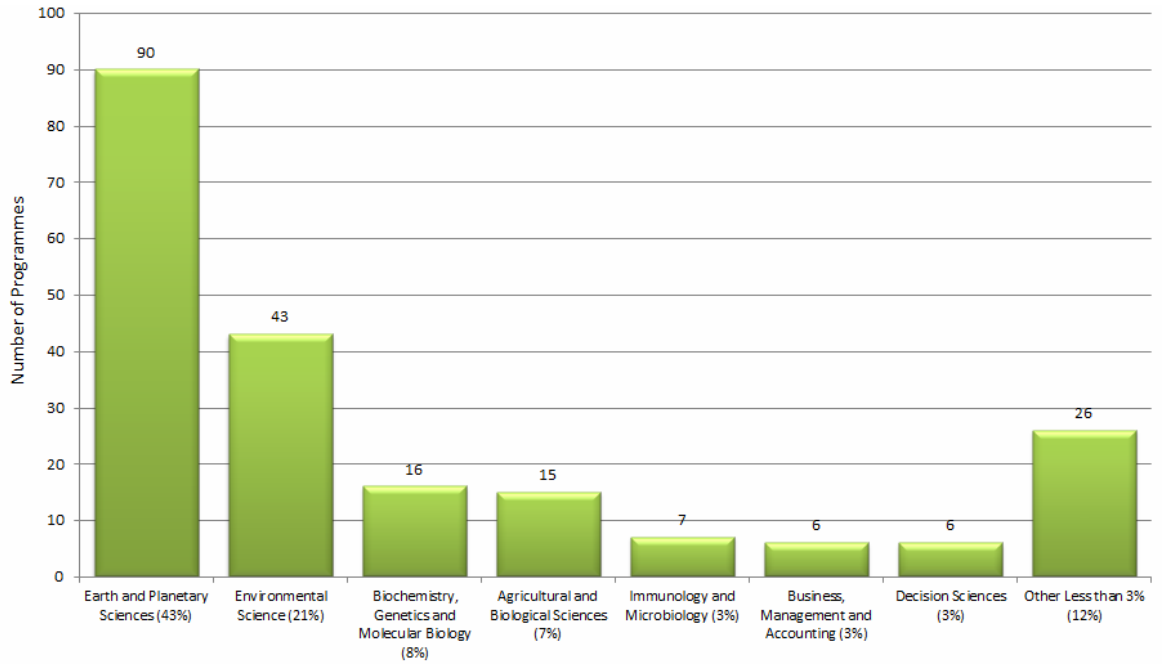

Figure 5. South African tertiary degree programmes in different GISc application fields

GISc, geomatics and remote sensing are widely included in degree programmes in Earth and planetary sciences, as well as environmental science. There are fewer degree programmes in agricultural and biological sciences that include GISc. Graduates of these programmes are likely to end up working in the *environmental balance dimension* of sustainable development. Most of these South African graduates will have had exposure to GISc during their studies.

GISc, geomatics and remote sensing are included in very few degree programmes in business, management and accounting. Graduates of these programmes work towards the *economic growth dimension* of sustainable development. Very few of these South African graduates will have had exposure to GISc during their studies.

Decision sciences is a wide application field that features in programmes such as town and regional planning, financial management, engineering, service sciences, supply chain management, marketing, stochastic models and transportation. Graduates of these programmes contribute to *decision-making* for sustainable development. Only a few South African graduates of these programmes will have had exposure to GISc during their studies.

Very few South African degree programmes in the social sciences include GISc. The Nexus search shows a slightly higher percentage of GISc applications in postgraduate research in the social sciences. Social sciences graduates are likely to work in the field of the *social inclusion and culture dimensions* of sustainable development.

6. Implications and Conclusion

GISc is widely included in South African tertiary degree programmes related to the environmental balance dimension of sustainable development, such as Earth and planetary sciences and environmental sciences. GISc education is not readily available in degree programmes related to the other three dimensions, namely economic growth, social inclusion and culture. An analysis of the current offerings of GISc education at South African universities, as well as recent Masters dissertations and PhD theses produced at these universities led to this conclusion.

The lack of GISc education in the other three dimensions may lead to challenges in the workplace where sustainable development is planned and implemented. For example, graduates in business, management and accounting often end up in managerial positions like municipal managers or financial managers of large organizations. Reports confirm that chartered accountants dominate the directorships of South Africa's largest listed companies (MoneyWeb 2013). Without adequate knowledge of GISc and GIS and an appreciation for the value of geographic information they may not support the allocation of funds for the acquisition, maintenance and use of geographic information and related systems.

The low number of programmes in decision sciences including GISc education is also worrisome. Graduates of programmes in decision sciences are most likely to end up in social and

physical planning positions such as town and regional planners or infrastructure planners. These types of applications have both a strong spatial and sustainable development component. A limited understanding of GISc and GIS in the workplace may lead to decisions that do not sufficiently consider the spatial implications of decision-making in support of sustainable development. The limited understanding is sometimes evident in the inefficient deliverable, for example, by the delivery of paper maps instead of digital information that can be shared and analyzed by many.

One may justly ask whether there is room for GISc education in the already full professional degree programmes of, for example, chartered accountants and engineers. The challenge is also to reach professionals in the workplace who graduated before GISc and GIS were widely included in degree programmes. As a result, in the foreseeable future, the need for short courses on topics, such as the value of geographic information and the basics of GIS, will remain.

The low number of application fields vs the large number of degree programmes in which GISc is included needs further investigation. The number of publications in the various application fields seems to be low, but further research is needed to determine how these numbers compare to the overall publication volumes in those application fields. It might also be that there are many more publications in which GIS is used as a tool (or method), but not mentioned in the abstract or title (and therefore not included in our study).

This study could be expanded in both breadth, e.g. to include all universities in the South African Development Community (SADC), and depth, e.g. by contacting individual universities to compare curricula in detail and to get student numbers. Further research is required to determine the demand for GISc education for sustainable development and whether the offering of a variety of GISc programmes at all South African universities is sustainable in the foreseeable future.

Looking beyond our borders, a further study of importance may be to determine how South Africa can contribute towards GISc education capacity in the rest of Africa. It is also important to compare this study with similar studies in other parts of the world. Such a comparison will reveal if the findings of this study in South Africa represent an international trend or rather a localized challenge. However, an initial search revealed that similar studies have not been done yet. A further study would be to investigate the inclusion of GISc education as part of sustainable development degree programmes in other parts of the world.

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