Challenges and Opportunities for the Advancement of GIS Education in TANZANIA

Neema Simon Sumari[1,2]   Zhenfeng Shao[1*]   Ernest Kira[3]

1.State Key Laboratory for Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University, Luoyo Road 129, Wuhan 430079, China

2.Department of Informatics and Computing, Solomon Mahlangu College of Science and Education, Sokoine University of Agriculture P.O. Box 3038, Morogoro, Tanzania

3.Department of Education, Solomon Mahlangu College of Science and Education, Sokoine University of Agriculture P.O. Box 3038, Morogoro, Tanzania

Abstract

Rapid developments in science and technology have driven utilization of Geographical Information Science (GIS) in various fields of Planning, Management, and exploitation of environmental resources and provision of social services. As information technology gains momentum, GIS uses information science infrastructure to address the problems of geography, cartography, geosciences locations and related branches of science and engineering; that is shortly referred to as Geo-informatics. Increased application of GIS calls for more demand of advanced Geo-informatics education worldwide. This study has established major challenges for the advancement of Geo-informatics education in Tanzania and any possible opportunities which can be utilized for the improvement of the same. Prominent challenges identified could be associated with lack of reliable power, internet connection, computer system and accessories and appropriate software. Other challenges were related to the nature of the school curriculum and insufficient knowledge and skills of the human resources. Opportunities identified involve available government plans for increasing power supply, increasing mobile phones networks, Tanzania ICT and education and training policy with a major aim of improving ICT education and the competency based school curriculum under implementation. But the government should further support directly or indirectly all efforts by various groups that participate in advancing Geo-informatics education in the country.

Keywords: Education, Geo-informatics, Tanzania, GIS, Transfer of Technology ICT

1. INTRODUCTION

Geographic Information Systems (GIS) technology has evolved over the past few decades to assist professionals in many disciplines (Goodchild 1992; Mwita, 2013; Li et al, 2014; Gong et al, 2017). This technology originated in land based applications but is now widely utilized in several diverse disciplines. Rapid development of computer hardware and software and sophisticated tools for capturing spatial information has accelerated the prominence of GIS (Raper and Green, 1992). This is the reason why it has been observed that development in the field of computers, satellite and information technology has led to a form of collapse of boundaries between professional fields. It is no longer certain where for example a surveyor starts, and a civil engineer takes over. This situation is seen as an opportunity for surveyors to expand her boundaries away from the core surveying fields into other fields such as environmental management, coastal management, geographic information system and remote sensing (Msakwa, 2017; Anderson et al, 2017). This will widen the scope of the practice and attract new intakes into the profession. There is certainly no reason why people with background in photogrammetry, remote sensing and geodesy cannot be brought into the field of surveyors and registered to practice in their special areas of interest (Nwilo and Osanwuta, 2004). This means the use of GIS in the era of information technology will prominently improve provision of social services (Li and Shao, 2009). For instance; the quality of life in urban areas largely depends on the availability of infrastructure such as water supply, waste disposal, road rail infrastructure, communication facility, house types, and availability of various other basic services, health, and education. This is by taking into account major facilities like educational facilities, hospitals, and industry. GIS can quickly analyse and display a route from a station or global positioning system (GPS) location to an emergency call (Manonmani, Prabaharan, Vidhya, & Ramalingam, 2012).

Studies show that there are numerous examples of the economic and societal benefits generated from the use of the growing technology of informatics in GIS. For example in Australia, substantial benefits could be realized across areas such as weather forecasting, onshore and offshore mining, mitigation and management of natural disasters like bushfires and floods, water resource management, design and assessment of conservation areas, insurance assessment, and land use planning. These services were estimated to have created more than 9000 jobs in 2015 and were projected to generate over 15,000 jobs by 2025 (ACIL Allen Consulting, 2015; Woodgate, et al., 2017). Considering another case, it is estimated that the geo-spatial data and services generate $1.6 trillion annually in the United States alone (OGC, 2015). This is the reason why a recent study by Gong et al (2017) concluded that Geo-informatics education is a key factor for sustainable development of geo-spatial sciences and industries. But for Geo-informatics to be able to play its role effectively it is important to identify

emerging issues that need to be observed.

Woodgate, et al (2017) identified major emerging issues that are determining the pace and course of Geo-informatics in various fields like: rapid urbanisation including demographic and social change, infrastructure development, shifting economic power and new business models, development of smart new green technologies that improve energy efficiency, reduce resource scarcity, and mitigate climate change, technological breakthroughs for example, in health or other social services, connected living (through enablers Internet, cloud, AI), sharing and circular economy, cognitive computing for automation of knowledge work and advanced robotics, quantum computing, smart cities, including autonomous vehicles and the move to artificial intelligence. All these issues affect all countries across the globe but not equally because they depend on three major factors: level of science and technology, economic growth and the system of governance. But it is important to note that the use of Geo-informatics in education is one of the means for addressing the challenges of science and technology, economic growth and the system of governance (Hall, 1999; Goodchild 1992; Mwita, 2013; Kumar et al, 2014; Scott, 2017) Therefore knowing the significance of GIS, It has been taught in Tanzania for more than two decades either as modules in some courses or as stand alone introductory courses, particularly in undergraduate programs.Students are taught about how to use GIS as a tool in the area such as environmental science, civil engineering, and geology but they do not learn GIS towards preparation for a career as professionals, scientist or researchers. There have been some efforts by various projects in Tanzania to advance GIS and GIS related fields like Universe Awareness (UNAWE), Telescopes to Tanzania and E-science café. Despite these efforts, there are important questions that remain unanswered. For example, can these efforts lead to the development of the required capacity? This question is pertinent because it has been observed that there is an urgent need of spatial data infrastructure (SDI) for urban planning and management, agriculture, mining, and disaster management; and hence, the development of a national SDI is highly prioritized (Becker, 2011; Mansourian et al, 2015). However, SDI planning, implementation, and management require detailed knowledge in the field, which is limited for the SDI stakeholders. The complexity of SDI in terms of the variety of affecting factors and the interactions between the factors, makes SDI planning a very complicated task in developing countries (Mansourian et al., 2015).

Even when SDI plan is in place, implementation of the plan needs political will as well. This means politicians at decision-making levels in the country need to be informed about the necessity of SDI, GIS or Geo-informatics in general. The scenario calls for diversified sources of information for raising awareness in the society through web linked data technology to facilitate the discovery of these resources (Yue et al., 2016). But the sustainable way of raising awareness is through education. This is the reason why Indian Institute of Remote Sensing studied the existing model syllabi of the All India Council for Technical Education and proposed a geospatial technology curriculum for bachelor and master's programs (Kumar et al., 2014). If the same programs are established in Tanzania, it is obvious that will set a milestone for the growth of Geo-informatics . But a question is what infrastructure is already in place for a reasonable growth pace and what are the limiting factors? Currently there are global efforts for etablisheing open access for web based resources such as close-range images, aerial images, satellite images, online algorithms, teaching materials and tutorials, open source software, computer vision source code and geodetic software (Gong et al., 2012). These web-based tools call for Massive Open Online Courses (MOOCs) and mobile applications for Geo-informatics education.

Despite the growing availability of Web-based educational products and E-learning courses, it is not easy to find appropriate educational material (Vyas and Koenig, 2014; Sefercik, 2017). The problem may be lessened if there can be regional and international cooperative efforts on the technical aspects of capacity building, advise, preparation of teaching and learning resources and mentoring young generation in the areas of Geo-informatics (Fukuda-Parr and Lopes, 2013; Gong, 2017). For developing countries like Tanzania, this problem may likely be complicated further by the limited resources for establishing the necessary infrastructure. But Just like other developing countries Tanzania interact with other countries at a global level as the waves of globalization intensify. Since globalization is mainly driven by the advancement of science and technology, some of the interactions between Tanzania and the other global countries are likely to be opportunities for the advancement of Geo-informatics in the country.

1.1 Statement of the Problem

Worldwide the field of Geo-informatics has been growing so fast because it has wide application in several sectors ranging from production, disaster management to governance. Advances in geo-informatics education are more prominent in developed countries though there are also considerable efforts taken by both public and private sectors in developing countries like Tanzania. Basics for learning Geo-informatics are considerably depending on the fields of science based subjects like Physics, Mathematics, ICT and Environmental education. Therefore, there is a need of establishing the main challenges related with the teaching and learning of these subjects that limit the development of Geo-informatics in Tanzania. Study observations such as the one done by Mwita (2013) revealed some challenges of learning spatial science in higher educations but did not investigate

how does the problem stem from lower levels of education. Also, it has been established that propagation of Geo-informatics in developing countries will depend on the levels of accessing web-based resources, local and international collaboration networks and capacity building capabilities (Mansourian et al., 2015; Yue et al., 2016). How these capabilities may be affected by limitations of the availability of both human and physical resources in the education system is not clearly investigated in Tanzania.

The study aims at establishing the major challenges and opportunities for advancement of Geo-informatics education in Tanzania.

2. METHODOLOGY

Asurvey research design was used in this study. It was possible to survey University instructors and secondary school students.

2.1 Target Population and Sampling Process

The target population consisted of University instructors and Secondary school students in Tanzania. Sampling process involved both probability and nonprobability techniques. Nonprobability one was used in selecting the universities and the instructors. The Universities selected were University of Dar-es-Salaam (UDSM) and Sokoine University of Agriculture (SUA). These Universities were selected based on the condition that they have been offering science based programs for quite long compared with other Universities. The heads of Department of Geography and Environmental studies, Mathematics, and Informatics from SUA and Heads of department of Geography, Mathematics and Computing and Physics from UDSM were sampled for the study. Four instructors from the named departments of the two Universities were randomly selected for the study.

Tanzania mainland currently has 31 regions but Morogoro region was chosen by the researchers for selecting secondary schools as it was convenient for the researchers to access the sampled groups easily. It should be noted that public schools in Tanzania use centralized curriculum and hence follow the same subject syllabuses prepared by Tanzania Institute of education. In selecting the schools from Morogoro region, the researchers established strata of private and public schools from both urban and rural Morogoro such that two schools were sampled from each locality. But of the two schools in either urban or rural one was a public school and the other a private one. This means the region was divided into strata in selecting the schools based on locality and type of school but in selecting the schools within the strata involved random procedure. From each school, ten students were randomly selected from a form four class where five students were from science combination while the other five students were from arts combination. These numbers of respondents were considered so as to ensure that the size of the focus discussion group does not exceed 12 individuals as studies show that most focus groups consist of between six and 12 people (Wong, 2008). Form four students were considered because they have already spent enough time in schools and their attitudes towards science reflect their real experience. The total sample size is 69 respondents as shown in *Table 1 below:*

***Table 1**. Sample composition, Field data (2017)*

		Males	Females	Total
From University	Instructors	16	4	20
	Heads of department	5	0	5
From Schools	Heads of schools	3	1	4
	Students	22	18	40
Total		46	23	69

2.2 Methods of Data Collection and Analysis

The researchers reviewed several relevant sources of literature that address GIS/ Geo-informatics initiatives in both developed and developing countries such as Journal and conference papers, books, private and public institutions web pages, video clips, workshop training materials and meeting summaries. Also, the researchers used observation check list to determine availability and status of various resources for teaching science and computer studies in schools and GIS at Universities. This was followed by interviewing the heads of the sampled University departments and secondary schools to determine the basis for the status of the available resources for teaching and learning science and GIS based programs, classroom pedagogy in use, human capacity and future prospects.

Further more, the researchers conducted two focus group discussions with University instructors and four other similar group discussion with students in schools. The size of each group discussion at the University level was 12 students whereas in schools was 10 students. Each focus group discussion was conducted for a maximum period of 40 minutes. The focus of the discussion was mainly on the challenges for the growth of science and technology education as a basis for the advancement of Geo-informatics . During focus group discussion, the researchers was probing questions while at the same time noting down the important issues relevant to the study. Most of the information collected was qualitative in nature and therefore was analyzed through content analysis.

But other data from students and instructors were coded, edited, named and relevant items were entered into the SPSS statistical tool so that the required percentages could be computed in order to generate meaningful comparisons and facilitate the interpretation of results.

3   RESULTS AND DISCUSSION
The section presents field data responses by using both direct and reported speech as it was found appropriate. The discussion involves reflecting on the major responses as a basis for clarifying the way various opportunities can be utilized to work through the challenges in order to advance Geo-informatics education in Tanzania.

3.1   *Challenges in Tanzania*
Challenges that retard the advancement of GIS education in Tanzania like any other developing country can be linked with the scarcity of both material and human resources. Even though GIS and ICT expertise is constantly increasing in Higher Education Institutions (HEIs) and in the society in general, there are difficulties of integrating GIS in education. This is complicated by the fact that GIS principles need IT infrastructures for managing, accessing, and using information. But the smooth use of the IT infrastructure in GIS needs some computational knowledge stemming from the lower levels of Education. A survey in schools identified that there is shortage of computers in schools and where the computer seems to be available they lack the necessary accessories like keyboard and mouse; they face a challenge for maintenance of computer hardware and software, purchasing of computers accessories such as printers and saving discs such as flash discs and CDs, including also computer anti-virus. The problem becomes intensified by the observation that in all the surveyed school's students are not allowed to possess mobile phones due to several reasons as pointed out by the school heads that: "*mobile phones waste much of the students' time and limit attention in classrooms. Also, students may use mobile phones to download unauthorized videos as they are still young*".

Computer course has not been made a core course although it has been the case in some private schools. For instance, Interview with the heads of the private schools found out that, computer studies subject is compulsory for forms I, II, III, and IV and it was indicated in the school time table. However, the interview with the head of the government school revealed that computer studies subject was the optional subject in her school in which it was indicated in the time table only for those students who opt for it and they also had to pay for it.

Even for schools which have computers were paying to maintain internet connections to cheaper internet service providers. But there was a challenge that the cheap ones attract a lot of customers hence the speed of internet has been reduced. The reduced speed has resulted in increased time spent during the search for learning materials. Hence, all heads of schools were of the view that schools should be funded so that they can afford getting connected to internet service providers with few customers and with reasonable internet speed for students to enjoy using it. The same applies even for Universities where Universities were opting for the cheapest internet provider just as it was being done by the schools. As a result, speed becomes very low. For instance, in one of the surveyed Universities, one instructor testified that:

> "*GIS needs practice; practice by both students and instructors at any time one gets the opportunity. Tell me with the internet speed of ours; suppose you have a class of several students where everyone is eager to see how GIS works using a software how long will it take for your class to get the means of the important issues of GIS? Consider your experience here in Tanzania where it may take several minutes to download a photograph of a few megabytes from the web. May be if you can have your class running at night when few people are loaded on the internet*".

But internet speed is not the only limit of using IT because among the surveyed instructors 5% of them never used computers when teaching their students except when processing examination results though they believe that Information technology can simplify the process of teaching and learning. Even for those who used computers they only used them in preparing power point presentations but 85% percent of them could not show evidence of utilizing web based resources like Skype, Teleconferencing, iPad/tablets or video clips/films. These web based resources for the case of GIS could be effectively utilized in education institutions with GIS laboratories.

Research shows that remote sensing and GIS laboratories are critically important in facilitating the teaching and learning process (Mwita, 2013). But in the surveyed Universities, there was no evidence of a laboratory for GIS facilities. Even facilities for teaching the other subjects from which GIS borrow some of its content such as Physics and Mathematics were quite insufficient in the surveyed Universities. The same applies to human resources such as instructors and technicians for the same subjects. The problem emanates from schools because in each of the schools surveyed was having a single science based combination whereas the arts were up to four in two of the schools. Through focus group discussion with the students, it was realized that students believed that science based subjects like physics are very difficulty and that they can only be studied by very bright students. For example one of the students who was studying arts combination declared that:

> "*I know myself that I cannot do science because science needs a lot of energy. I know that there are several*

students whose ability is just like mine but they have opted for science! We will soon see their zero when their National examination results are out. It has been a practice in this school that very few science students score grades that are high enough to make them continue with advanced level studies. But for my case, I'm sure that I will pass National examination results".

The problem is complicated with ashortage of science teachers. For instance among the four schools surveyed scarcity of teachers was more serious for science subjects where two of the schools that based in the rural area were having only one physics teacher; teaching from form one to four. The observation was in line with research findings that, performance in most science subjects is poor, but that of mathematics and physics were comparatively poorer. The problem is compounded by the lack of qualified teachers (Lujara et al, 2006; Sife et al, 2007; Kira and Mahumbwe, 2015)

A number of hands on activities are also required for GIS learners to be conversant with the programs and the best ways to handle the data (Hastings and Clark, 1992). This calls for student centered approaches in Higher learning institutions. One of the student centered, pedagogies in higher learning institutions is problem-based learning. Problem Based Learning appears to have become the preferred pedagogical strategy in tertiary education worldwide (Amoako-Sakyi & Amonoo-Kuofi, 2015; van Genderen, 1992; Kerski et al, 2013). This is contrary to the observations of this study where all the surveyed University instructors acknowledged that they are still practicing traditional methods of instruction which are teacher centred.

One may expect that as GIS gains momentum in various fields of planning, environmental management, and production, the same GIS knowledge and skills may diffuse towards educational institutions as both University instructors and students interact with various sectors in the field of work. But survey of this study has demonstrated that there is very weak link between schools, universities, and industries. For instance, the surveyed instructors agreed that, there is a low degree of integrating various types of outdoor activities with teaching such as use of social media, community services provided in various sectors, industrial developments, field expeditions, workshops and farm production units. This observation can be linked with limited exposure of the University instructors regarding the role of integrating various types of outdoor activities with teaching in improving the curricula under implementation. The evidence is that during focus group discussion with the instructor they were of the view that their programs have up-to-date curricula; although (25%) of them disagreed that curriculum is reviewed regularly. The same applies to involving important external stakeholders in curriculum review as a means of improving the curriculum. It implies that propagation of GIS/ Geo-informatics in the community cannot be directly reflected in the educational institutions unless deliberate efforts are taken.

The challenge of using student centered methods as an effective means to teaching GIS seems to manifest in Higher learning institutions because Universities struggle with enrolling big numbers of students which do not match with the numbers of instructors. The problem intensifies in those Universities with many science programs where the majority of both staff and students are males. For instance, data from SUA, a university with less number of non-science based programs than the other Univesity surveyed show that, there is inequality in enrollment at all levels where female student's counts only 30% of all undergraduate and diploma students. The gap in enrollment is coupled with another twin problem of having 80% male academic staff.

4   CONCLUSIONS AND RECOMMENDATIONS

The study has revealed that lack of appropriate technology sets a significant barrier to the development of Geo-informatics. Since solution for this problem partly needs financial resources; political will is required so that the issue stands as a priority in the National annual budgets. Never the less already there are plans in the country to address the issue of power supply especially for the rural population of schools. For instance, the country aims to generate adequate, reliable, affordable and environmentally friendly electricity supply from various sources particularly from natural gas exploitation so as to increase the installed power capacity from 1,583 MW to at least 10,000 MW by 2025 and also expand transmission and distribution systems (URT, 2014). This should drive installation of computer and computer accessories in educational institutions for the more effective way of teaching science subjects in schools as a basis for Geo-informatics in higher learning institutions. Although there is a challenge that computer systems may be expensive for schools to access, there is evidence that the growth rate of using mobile phones can partly address the problem. Consider the observation that at the end of 2015, 46% of the population in Africa subscribed to mobile services. Within five years, it was projected that an additional 168 million people will be connected by mobile services across Africa, reaching 725 million unique subscribers by 2020. Eight markets will account for the majority of this growth, most notably Nigeria, Ethiopia, and Tanzania, which will together contribute more than a third of new subscribers (GSMA, 2016).

Also, use of technology has been identified as a priority area among several countries. For instance, in Tanzania national ICT policy as supported by education and training policy, information and technology introduce new opportunity to support education and to improve the quality of education in different areas (URT, 2014).

But it should also be noted that availability of appropriate technology is only one stage among several other

stages along the journey as observations in this study have demonstrated cases where technology like computers was underutilized. The observation concurs with the findings that, availability of technology alone does not have an educational value unless several other factors are also considered (Mahumbwe and Kira, 2016; Tezci, 2009). The educational technology process should begin with the identification of an educational problem and decide what students, teachers or schools want to achieve (Neyland, 2011; Tezci, 2009; Kira and Komba, 2016). There must be focused capacity building to ensure that; firstly, policy makers understand the role of Geo-informatics in social economic development for effective implementation of the already formulated ICT and education policy. Secondly, Experts of GIS and Geo-informatics need to acquire the required expertise to be able to implement worldwide recommendations of improving Geo-informatics education. For instance, this study has revealed that there is underutilization of computer systems in education institutions such that there is limited ability to access web-based geospatial resources and less use of e-learning and teaching methodologies. The situation will also limit the ability to establish regional cooperation and international collaborative education programs though recommended for advancing Geo-informatics (Fukuda-Parr and Lopes, 2013).

Underutilization of ICT in the higher levels of education can be associated with lack of strong foundation of ICT background. For instance, this study revealed that Computer subject is not a core course in public primary or secondary schools. It implies that it is possible to have students getting into the higher levels of education without interacting with a computer system as a tool for learning. Therefore, among the important issues to be considered when revising the school curriculum should be introducing ICT as a mandatory subject in schools so that students get familiar with web based learning resources from their lower levels of education. This should go together with the use of supporting devices like mobile phones, iPads and camera by students in schools. Although the school heads mentioned some disadvantages of allowing students to possess mobile phones, measures could focus on ensuring that they use mobile phones under restricted environment rather than banning them completely because applications of such tools diversify tremendously with the intensity of globalizaion. For instance, if some concepts of GIS were to be introduced in the school curriculum so as to start raising up the awareness of students right from schools, mobile phones could assist significantly on how to apply information technology in GIS.

Already, there is an opportunity in the lower levels of education for instance in Tanzania where in 2005 the government through Tanzania Institute of Education (TIE) revised the secondary school curricula into competency-based curricula (CBC) with the aim of equipping school graduates with sufficient knowledge and life skills for them to survive academically and socially in the modern world (Kitta and Tilya, 2010). The change is a message to all educational institutions in the country that teaching, and learning should focus the world outside of the schools and Universities. For instance, if GIS is a technology being practiced in the provision of social services, extraction of environmental resources and in conservation, there must be immediate deliberate efforts of ensuring that the same knowledge and skills features in the appropriate levels of the school curriculum.

Unfortunately, the limited school-industrial link in developing countries deprive the schools not only with the most current and useful technology but also with the opportunities of outdoor learning. For instance, in South Africa where there has been more improvement in information technology and the practice of GIS both in schools and in the outside world, can be associated with the increased outdoor learning opportunities as schools could practice industrial production skills. Considering 288 peri-urban schools that registered for the School Enterprise Challenge in South Africa in 2015; students in these schools have set up school enterprises such as recycling waste, school snack shops, and beaded jewelry making, generating profits of up to €448 in 3 months (Education that pays for itself Charity group, 2011). In Tanzania, this opportunity could successfully be emulated by education institutions especially Universities. For example, consider the observation that the use of information technology in GIS has already been identified as a fast-growing field of education. Universities could advertise themselves as agencies which provide GIS to the required levels of competences. Provision of such services in these institutions could not only act as a means of income generating activities but also could have several multiplier effects such as means for acquiring the required teaching and learning resources, means for effective student-centered pedagogy and also means for attracting university applicants from schools towards science based programs including Geo-informatics .

Also, it should be noted that Universities stand at a better position for supporting the activities of advancing Geo-informatics education by various groups such as Universe Awareness (UNAWE) and Telescopes to Tanzania by sharing both material and human resources. More importantly, this education institution should do more research to determine the most appropriate way of advancing Geo-informatics for its effective utilization in the society. The government can further support directly by providing some important resources to the educational institutions or these champion groups. Indirect support can be through amendment of policy, rules, and regulations to facilitate ease access of resources for teaching science based subjects, GIS or Geo-informatics such as computer systems and accessories, software and mobile phones at various levels of education.

5 CONCLUSION

There are initiatives taken in the sub-Saharan Africa to improve Geo-informatics education because it has been observed that it is a growing field of study which can simplify several aspects of environmental resource exploitation, management, and service provision (van Genderen, 1992; GSMA, 2016). The use of information technology in GIS in developing countries is a growing field of study in educational institutions. Despite these initiatives, various countries of sub-Saharan Africa face different challenges and opportunities. But generally, these challenges can be associated with but not limited to Scarcity of both human and material resources, Inappropriate program curricular for effectively accommodating GIS knowledge and skills and inappropriate science pedagogy in both schools and higher learning institutions. In order for the field of Geo-informatics education to grow at a reasonable rate; change should involve all education stakeholders who are students, parents, teachers/instructors and the state leaders at all levels. But the magnitude and direction of the change should be determined by doing further research.

Authors

Neema Simon Sumari, Ph.D. Researcher in Geo-Spatial Information Science, with specializing in Remote Sensing, Cartography and Geographical Information Engineering, at LIESMARS (Laboratory of Information Engineering in Surveying, Mapping, and Remote Sensing), Wuhan University at the time of writing. She obtained her MSc and BSc both in Computer Science at Alabama Agricultural and Mechanical University in the United States of America in 2011 and 2006. ORCID Neema Sumari, http:orcid.org/0000/0001-9664-051x

Zhenfeng Shao, a full Professor at the Wuhan University, China, received the Ph.D. degree in photogrammetry and remote sensing from Wuhan University, Wuhan, China, in 2004, working with the State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS). His research interests include high-resolution image processing, and remote sensing applications. Dr. Shao was a recipient of the Talbert Abrams Award for Best Paper in Image matching from the American Society for Photogrammetry and Remote Sensing in 2014, the New Century Excellent Talents in University from the Ministry of Education of China in 2012.

Ernest Kira, a Sinior Lecturer at Sokoine University of Agriculture (SUA), Tanzania, received his PhD. degree in Education from the University of Dar-es-salaam, Tanzania, in 2014. He has served at SUA for more than seven years. His research interests include educational research, curriculum and Science Education. Dr. Kira, has been involved in teaching, conducting research and offering consultancy services in the afore mentioned areas of expertise.

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