OPEN SOURCE SOFTWARE AS ALTERNATIVE TO GIS SOFTWARE PIRACY IN DEVELOPING COUNTRIES: ANALYSIS OF PERCEPTION OF KEY PARTICIPANTS IN GEOGRAPHICAL INFORMATION KNOWLEDGE TRANSFER IN NIGERIA

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ABSTRACT

While software and data piracy attract penalty in developed countries, it is a widespread practice in many developing countries where adoption of Remote Sensing and Geographical Information Systems (RS and GIS) is prominent, though rapidly evolving, RS and GIS is largely characterized by high costs of 'high profile' software, hardware and high-resolution imageries. This study focused on the assessment of the perception on open-source GIS software in selected institutions across Nigeria. Ten tertiary institutions (comprising of universities and GIS training centres, with curricula for postgraduate programmes in the field) and two privately-owned GIS-based organizations were selected for investigation on the kinds and methods of acquisition of software, as well as their reactions to open-source software's usage and the challenges of using them. Data for the research comprised of used and preferred software from key informants such as Directors of Programmes or Coordinators in the Departments offering the courses in these institutions, selected students and trainers/lecturers/instructors of the programmes. Results from this study exposed the use, progress, and nature of software usage in spatial data collection and analysis in a typical developing country in sub-Saharan Africa. Results showed that the perception to Open-Source GIS software was positive and 80% will definitely use it. Results further showed that all the participants cited financial constraints as justification for the use of 'cracked' GIS software. This study recommends manpower capacity for GIS applications to further develop GIS trainers in open-source GIS software. Also, introduction of studies on software, particularly open-source GIS software into the GIS curriculum in all the institutions building capacity in the field is recommended.

Keywords: Developing countries, GIS, Knowledge transfer, Open source data and software, Software piracy.

INTRODUCTION

The geographical information system or geo-information science (GIS) is regarded as a system that involves the collection and management of spatial data whose handling focuses on finding solution to earth-referenced problems (Steiniger et al., 2008). GIS is a computerized system consisting of data acquisition, management and information presentation (customized) subsystems. Data required for many problems (either physical, social or thematic) are often complex, requiring collaboration of different people and use of diverse approaches. Applications of GIS and its subsystems have played prominent role in data management and decision support systems in diverse areas of life. For example, Masser (1998) describes the recognition of the potentials of GIS in parts of Europe and North America. Masser (1998), among others, revealed the existence of information-rich and information-poor societies as a function of attitude and

decision of governments, societal awareness, infrastructure and preparedness. Despite the gaps in the software usage and applications in GIS across developed, developing and underdeveloped societies, studies have shown that its principles and infrastructure are considered important to national development, especially in the area of education, health and land planning and management (Cooper et al., 2001; Olowu, 2003; Baker et al., 2009; Mentis et al., 2015).

In Nigeria, as typical of many developed countries, especially in tropical Africa, GIS is rapidly growing in the educational sector, with its strength for creation of employment in computing technology and advancement in many developmental programmes (Ikhoria, 1995; Fadahunsi, 2010; Odia & Odia, 2013; Nwankwo et al., 2013). Researches are also progressing in the application of the principles and infrastructure of GIS in almost every aspect of the ecological systems that are of sectoral, community or national interests. Such studies include, Mengistu & Salami (2007) and Eludoyin & Iyanda (2018) on forest studies, Olowu, (2003), Mentis et al. (2015) on governance, Aguda & Uyeh (2012), Fashae et al. (2014) on water resources and Eludoyin et al. (2014) on climate regionalization and thermal comfort. These studies revealed the growing interests in the field of GIS in Nigeria. Also, the numbers of Universities, Colleges and training institutes teaching or building human capacity in the area of GIS has increased in the last two decades (Kerski et al., 2013; Williams et al., 2022). For instance, whereas the University of Ibadan and Federal School of Surveying, Oyo were known for dedicated programmes (professional Master of Science and Postgraduate Diploma, respectively) in GIS between 1995 and 2000, at least two Universities (Obafemi Awolowo University, Ile-Ife and Nigerian Defence Academy, Kaduna) now offer the course at doctoral level; many Universities, Colleges and Polytechnics now offer different programmes in the field. In all, the field of GIS is now important in the Nigerian educational curriculum.

Components of a GIS include the hardware, software, data (database), procedure and the people (users and expertise) (Guanfu & Ershun, 1998; Malczewski, 2006). Whereas many sub-Saharan countries, including Nigeria may possess required expertise and markets, they – at present - depend on international organisations and technologically advanced countries for the hardware and software; either through importation, support or gifts (Smith et al., 1996; Asemi & Jazi, 2010; Mzuza & Van der Westhuizen, 2019; Yau et al., 2019). Mzuza and Van der Westhuizen (2019) argued that GIS in Botswana received significant financial and technical supports from international organisations. On the other hands, whereas Mzuza and Van der Westhuizen (2019) reported that the Nigerian Federal Government's Education Reform of 2007 dictated that GIS should be included in the secondary school curriculum (Danjuma & Ubayo, 2014), an investigation on the recent secondary curriculum indicates that the subject of Geography through which GIS can be incorporated has now been made optional, and only required for social science or commercial students (Ajayi & Bifarin, 2018). Rather than Geography, subjects such as Animal Husbandry and Civic Education are made compulsory at Secondary Schools level (Awofala & Sopekan, 2013; Adejuyigbe & Adejuyigbe, 2016). However, it is correct to note that in most other West African countries, GIS is taught only at tertiary education level (in most cases as part of Geography, Ecology and Environmental Studies or Land Surveying – surveying and geoinformatics), probably because of a lack of recognition of its importance, the rigid structure of the local traditional education system and a shortage – induced by cost - of resources such as computer hardware and software (Buabeng-Andoh, 2012; Ikhuoria, 1999; Mzuza & Van der Westhuizen, 2019).

Free software allows us to know and adapt its source code to the needs of each user and gives the freedom to reproduce and distribute copies for the benefit of society (Stallman, 2015). An Open Source Software (OSS) is a software whose source code is available to the general public for use 'as it is' or with modifications; they are generally without a license fee. Rosas-Chavoya et al. (2022) while citing Robles et al. (2019) hinted that science is closely related to the Free Software concept for the fact that one of the most important aspects of science is reproducibility, a feature which allows anyone to test data, hypothesis, and methods, makes free software an ideal framework for the scientific work. Sowe (2011) noted that the principle of Open-Source Software (OSS) is based on the need to ensure free access by making the source code of software accessible. The OSS is often hoisted on a platform of technologies that are expected to provide for sustainable development while being designed in the same fashion as free and open source software (Wong & Sayo, 2006; Buitenhuis & Pearce, 2010; Pearce, 2012). However, how acceptable and popular is the use of free or open software as against the commercial GIS software?

The objectives of the postgraduate programmes in GIS at the Obafemi Awolowo University, Ile-Ife, Nigeria as typical of the focus of the field in Nigeria are to (a) create opportunity for the academics who might want to develop their skills in the area of GIS; (b) enhance capacity and capability for research development; (c) enable candidates to acquire thorough knowledge in specific areas of GIS; (d) enable candidates undertake researches in specific areas of GIS, that will facilitate the advancement of the discipline; and (d) increase the levels of manpower in the field. The University made use of GIS in the context of geo-information science to indicate that it is the 'science' – which comprises the philosophy, technicalities, implementation and management - of the system that constitutes her focus. Many institutions have focused primarily on the technicalities and implementation, and have thus highlighted the significance of the 'system' rather than the 'science'. All the institutions in Nigeria, focusing either on technicalities or the science, have involved the use of software, and are all challenged with the costs and availability of GIS software.

GIS software use in universities across Nigeria may probably be an effective way to show the development of the field of study. Prior to 1998, the Department of Geography at the University of Ibadan was the only institution offering a GIS programme, and that was in connection with the University of Iowa, in the United States of America (Areola, 1998). As such, the dominant software was the ArcInfo (a proprietary command line-based GIS software that was first released in 1982 by the Environmental Systems Research Institute (ESRI), which was provided under a linkage agreement with the two Universities.

Dekolo and Oduwaye (2005) argued that the University of Lagos had also commenced desktop GIS programme since 1988, but that was incorporated into the programmes within the Department of Geography, as well as Surveying and Geoinformatics, where MapInfo and Atlas GIS that are proprietary GIS software were commonly used. In 1998, the first set of GIS at the Federal School of Surveying, Oyo, Nigeria, were exposed to ArcView and Integrated Land and Water Information System (ILWIS) software, which were both proprietary and expensive. ILWIS was popular in the institution and the Regional Centre for Training in Aerospace Surveys in Nigeria at the time because of the collaboration between the institutions and the International Institute for Geoinformation Science and Earth Observation (ITC), Enschede, the Netherlands.

Participants in GIS in most institutions in Nigeria since 2000s have been mostly exposed to TerraSet or IDRISI GIS software, developed by Clark Labs at Clark University, Worcester MA, United States of America (Eastman 2003), which became introduced into the country as 'an extremely low-priced', raster-based GIS that is able to provide the range of functions for remote sensing analysis and GIS (Meaden & Kapetsky 1991); and ArcGIS, an advanced product of ESRI through the low-cost licenses programme for the academic community' in many developing countries, including Nigeria. Consequently, most of the available proprietary GIS software are pirated ('cracked') by students, and are transferred to friends for a token.

This study is aimed at examining the perception of trainers, users and students of GIS in selected institutions in Nigeria about open source and non-proprietary software. The objectives were to determine the reaction to and awareness of Open Source GIS Software (OSGS) - whose source code is available to the public with or without modifications - by people (users and experts) in the selected institutions and organisations, as well as identify the problems that militate against the preference of OSGS in the area.

MATERIALS AND METHODS

The study area comprises the selected Universities and non-governmental organisations that are involved in the use and training of geographic information systems in different parts of Nigeria, especially in Osun, Ondo, Oyo, Kwara, and Abia States. Data used for the study were responses from purposively (based on their experience) selected trainers and users of Remote Sensing and GIS in selected Federal government owned universities (Universities of Ilorin, Ibadan and Lagos, Obafemi Awolowo University, Ile-Ife, Federal University, Akure), States owned universities (Abia State University, Uturu, Adekunle Ajasin University, Akungba-Akoko, Ondo State, and Ladoke Akintola University, Ogbomoso, Ondo State).

Data were also obtained from two international organisations (African Regional Institute for Geospatial Science and Technology, formerly RECTAS, and African Regional Centre for Space Science and Technology Education - English, Ile-Ife), and two privately owned organisations (Geospatial Data Solutions, Lagos and Greenland Consult, Ibadan) (Figure 1). From each institution, an individual who was responsible for the organization or training as well as five trainees/students were purposively selected as key informants and were questioned on existing GIS tools, awareness and perception of open software tools as well as challenges facing the adoption/implementation of GIS in their organisations.

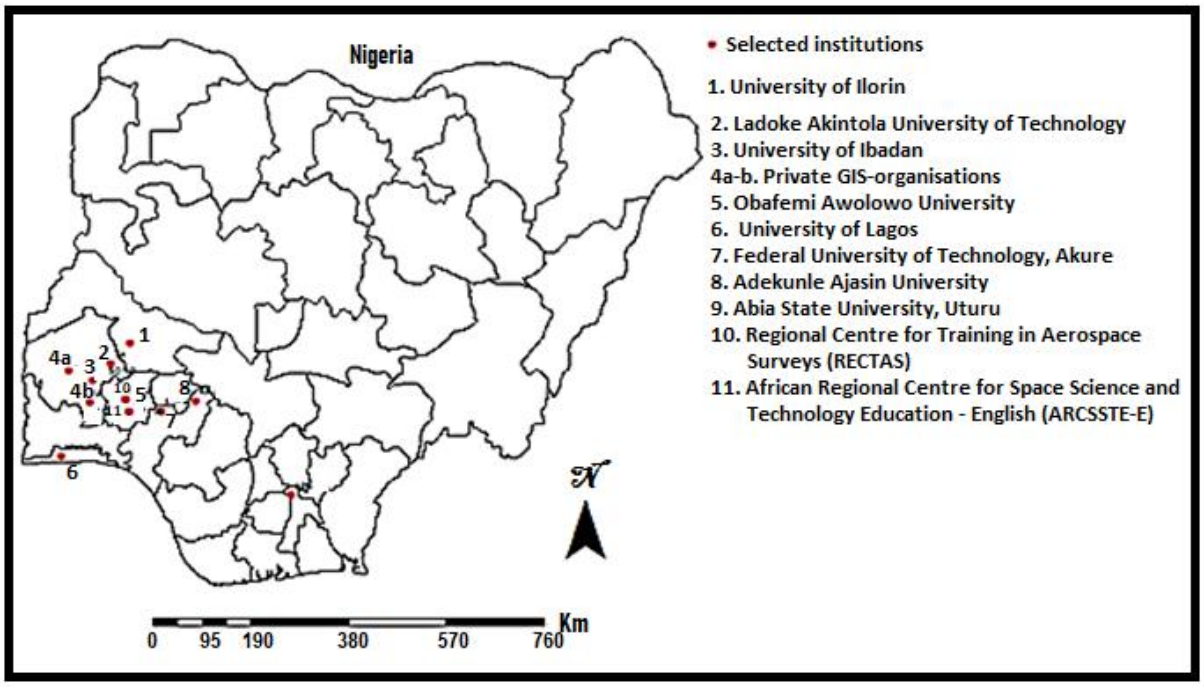

Figure 1. Distribution of selected institutions and private GIS organisations

RESULTS AND DISCUSSION

Perception on Open Source GIS Software

Results showed that the perception to Open-Source (OS) GIS software was positive (80%), and only 16.7% of the respondents were indifferent. Over 83% also think OS GIS software are innovative, and 80% will definitely use it; indeed, all the respondents will likely use it for their research or learn it. On a range of 0 – 10 (in increasing potentials), 84% ranked the use of OS GIS software greater than 7, and in general, majority of the respondents will prefer OS GIS for being freely available (Table 1). Table 2 shows the list of software used for geographical information analysis by the participants in the study area. Out of the identified software, only Sentinel Application Platform (SNAP), System for Automated Geoscientific Analysis (SAGA), Q (Quantum) GIS, Integrated Land and Water Information System (ILWIS) version 3.8 were appropriately identified for GIS analysis; the Hydrologic Engineering Centre's River Analysis Software (HEC-RAS) was specifically identified as specialised 'third party' software in GIS environment. GIS software is characterized by capacity for integrated cartographical and attribute databases storage, manipulation and analysis, as well as information presentation. Only the participants from the private organizations claimed that they use the OS as none of the participants from the institutions make use of any, despite their awareness of their (OS software) existence. On the other hand, an evaluation of existing records of OS GIS software suggested that the participants do not remember more than 70% of popular ones; a situation that suggests inadequate awareness about the software.

Table 1: Perception on adoption of Open Source GIS software among Trainers and Users in Nigeria

Questions	Dominant responses	% Responses
Reaction to open source GIS software	Very positive	83.3
	Neutral	16.7
How innovative is the open-source software	Extremely	33.3
	Very	33.6
	Somewhat	16.7
	Not known	16.4
Is OS GIS software what you need?	Definitely	80
	Probably	20
How likely would you be to use OS	Very	100
How likely (on the scale of 0 – 10) will you recommend OS?	0 - 6	16
	7 – 8	67
	9 – 10	17
What are things to improve	Affordability	45
	Processing speed and accuracy	15
	Integration of key performance indicator for monitoring stake holders' activities	40

Table 2. Examples of open access GIS software, their identification, and commonly pirated proprietary GIS software in the study area

Open Source GIS software (OSGIS)	Participants' identification OSGIS software	Wrongly identified OSGIS by participants	Commonly pirated ('cracked') Proprietary GIS software
Sentinel Toolbox (Sentinel 1-3)	Identified as Sentinel Application Platform or SNAP 6.0.	HEC-RAS	ArcMap (10.2)
QGIS Semi-automatic plug in	Identified as QGIS		ENVI 5.0.1
System for Automated Geoscientific Analysis (SAGA) GIS	Yes		Idrisi Selva
Optical and Radar Federated Earth Observation (ORFEO) Toolbox	Not identified		Erdas Imagine
PolSARPro	Not identified		ArcGIS
Opticks	Not identified		
Open Source Software Image Map (OSSIM)	Not identified		
Inter.Image	Not identified		
ILWIS	Identified		
gvSIG	Not identified		
Whitebox GAT	Not identified		
E-foto	Not identified		

State of Remote Sensing and GIS

All the institutions visited were well equipped with computer accessories required for the implementation of remote sensing and GIS curriculum; many of the Universities and the other institutions have at least a decent laboratory for the programme. Although they appeared in good state, their functionality could not be ascertained as all of them were not in use at the time of the study. The commonest GIS software was ArcGIS, although over 80% of the trainers claimed to have installed other software, including Idrisi and ILWIS on their personal computers. Analysis of responses from the training institutions indicated that the lecturers/instructors were not often encouraged to undertake additional programmes in the use of GIS software. This is occasioned by poor funding, interest or poor level of awareness of the need for such. One of the technologists interviewed noted that:

> *'it is mostly assumed that once an instructor has at least a postgraduate diploma in GIS, s/he is capable of teaching both practical and theory of GIS, even when it is obvious that he has a faint practical knowledge or experience of the field of study'.*

In another perspective, a key informant in one of the private organizations declared that:

> *'many graduates of remote sensing and geographical information system from Nigerian institutions often lack adequate quantitative techniques and use of advanced programming languages…. majority do not even understand scripts'*

Sixty-five (65%) of the lecturers or instructors interacted with during the course of this study had not undergone any specialized training in GIS applications or concept training in the past five years; 55% have however participated in conferences, basically because such attendance was required for their promotion in the following year. Knowledge acquisition often require payments but many of the participants complained that incentives were difficult to obtain, and that although the Universities' authorities in Nigeria through the Tertiary Education Training Fund (TETFund) sponsor selected conferences' attendance and doctorate degrees of staff but not Short courses, where specific technical trainings are provided. Also, poor or expensive internet facilities along with unstable electricity supply in many parts of the country jeopardize the capacity to download or acquire training online. Manpower capacity development tends to be greater with private organizations than with the public institutions or training agencies in Nigeria, probably because of the competition required in private organisations. For the students in training, programming languages such as python, R, are rarely taught outside Engineering faculty, particularly in the Department of Computer Science /and Engineering, and most '*GIS specialists do not understand Linux operating system, the platform on which most OSGIS run*' (*per. com*., a computer scientist at Ladoke Akintola University, Nigeria).

Open Source software in RS and GIS curriculum

All the institutions where participants were sought have programmes and specialized courses in the undergraduate and graduate curricula for Remote sensing and GIS, but none of the curriculum treats GIS software as a course of study. An evaluation of the courses taught showed that software is not in the focus. Also, the curricula lack training in programming languages that will be required by users to write scripts in the open source software, in case of the need for manipulating the codes.

Many of the programmes, apparently, do not build capacity for use of the open source software, as most users were comfortable with window-based software. In most cases, the poor training in programming languages for remote sensing and GIS may be explained by poor nature of interdisciplinary perspective of research and trainings in the region. For example, personal observation across many universities in Nigeria reveals that except for Faculties of Health Sciences, multiple-authored publications are often discouraged in most other faculties. Department of Geography houses Remote Sensing and GIS in the University of Ibadan, University of Lagos, Obafemi Awolowo University, Adekunle Ajasin University, except in the Federal University of Technology, Akure, where Remote Sensing and Geoscience Information System programmes exist in separate Departments. In all of these, multiple-authored publications were rarely considered as strong as contributors are often scored based on the position of their names – scores often decreased from the first to the last author. The implications of the poor interdisciplinary approach to research include poor inter-department or inter-school collaborative research. Consequently, although the policy for approval of these courses often

necessitates the use of associate lecturers from other fields, including computer science and engineering, this is very rarely the case in all the Universities.

However, recent studies have revealed that Quantum (Q) GIS has become popular in publications from both developing and developed countries (Khan & Mohiuddin, 2018; Flenniken et al., 2020; Rosas-Chavoya et al., 2022). Evaluation of studies from Nigeria however indicate that the open source GIS software is currently undervalued, and are less projected in research outputs than the proprietary software. Recent studies by some authors (Korkovelos et al., 2019; Butcher et al., 2021; Eludoyin & Adewole, 2020) among others have showcased the usefulness of freely available remote sensing data, and argued that they present results that are capable of supporting important policy-related decision for sustainable management.

Issues of software piracy

Participants were inquired if they knew that using pirated or 'cracked' software was a punishable offence, to which majority noted in affirmation. Although the Nigerian Copyright Act: Anti-piracy measures (1999 No. 42) provides a conviction of a fine not exceeding ₦50,000 ($138.9) for software pirates within Nigeria and ₦500,000 ($1,389) to those who import counterfeits into the country, piracy of software has never been punished in any of the institutions visited. Therefore, all the participants would rather provide alibi of financial constraints to justify use of 'cracked' software but were not sure if they would desist or not. One of the participants at the Federal Government sponsored Space programmes noted that:

> '*the school introduced us to the use of some proprietary software, particularly ArcGIS and Erdas Imagine, but they have not renewed the license since 2016, hence majority of the students must devise ways of installing the cracked versions on their personal computers'.*

Another participant, a postgraduate student argued that '*if we do not 'crack' wetin we gain?'*, suggesting that they (students) do not have any alternative than pirate the proprietary GIS software. It is however unclear if most of the proprietary GIS software pirates consider their actions as being wrong and socially unacceptable as described by Harran et al (2015). One of the key informants actually argued that:

> *'I do not commit any offence since I only use it for my school assignment. I do not sell it. By the way, my University does not renew the license of the original version'*

This informant's perception almost cuts across the students in many of the Universities, where even the installed proprietary GIS software for training purpose were 'cracked' (pirated). It is well reported, as observed by this study, that tertiary education (especially Universities) in Nigeria are poorly funded, and GIS may not be an exemption. While we think that private Universities may fare better, probably because they are not likely to be affected by political bureaucracy, none of those in Nigeria claim to train students or manpower in GIS. The perception also differs from the hypothesis of McIllwain (2007) that (electronic) piracy may be an act of an organized crime.

Furthermore, although piracy is regarded as a crime, over 70% of the participants used in this study apparently did not care, and they complained of poor funding of GIS programmes. On the other hand, an assessment of their responses on OSGIS software showed poor awareness of the existence of the software. While the marketing and advertising structure that makes users trust proprietary software may be a factor in this case, the fact that graduates of GIS programmes in the country are very likely to be incompetent in the use of the operating system of most of the open-access software cannot be over-emphasized. GIS departments need competent programmers and computer scientists, and not always application trainers that are primarily social and environmental scientists. In addition, manpower capacity for GIS applications will benefits from further development of GIS trainers in open source GIS software.

CONCLUSION

Discussion on software piracy in a developing country like Nigeria can be multidimensional. While it is a crime in the legal sector and there is a binding regulation, piracy is rarely punished. Okorodudu-Fubara (1998) argued that although there are laws but they are hardly enforced, and like in many other sectors, many legal provisions are rarely punitive. In this study, a number of factors are observed to affect the behaviour of those who pirate GIS software, and these include ignorance of freely available, Open Source GIS software that can provide similar, and sometimes better results or outputs than the proprietary GIS software.

The paper highlights the trends of Open Source GIS software adoption as alternative to the piracies of proprietary software in developing countries using the Nigerian example. The study found that users of GIS technology in developing countries adopt the use of open source and pirated software as a result of the incompetent technical and know-how knowledge, lack of appropriate technologies and financial constraints. Software piracy is a common crime among both trainers and students of GIS in Nigeria, as typical of occurrences in many developing countries. Results of the analysis of participants' perception showed that improved awareness and capability to use the open source GIS software as well as GIS data are capable of reducing or eliminating the crime. Software piracy among either trainer or users is not based on economic justifications and is not in a form of an organized crime. Introduction of studies on software, particularly open-source GIS software into the GIS curriculum in all the institutions building capacity in the field is recommended.

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