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Utilisation of Information and Communication Technology for Environmental Sustainability: A Global Perspective

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Abstract

There has been a rapid development of Information and Communication Technologies (ICTs) globally, and ICT have been used as a tool to attain environment sustainability all over the world. There are diverse environmental challenges faced by developing countries such as ecosystem deterioration, pollution, resource depletion, loss of biodiversity and climate change and the management of above problems is difficult because they involve multiple actors and its occurrence is over time and space. Environmental Scientists have raised concerns on how these environmental challenges can be tackled bringing into lamplight, how ICT and environmental science research can be used to wedge these challenges in developing countries. The study is exploratory and employed the use of survey questionnaires as an instrument to collect data. Findings revealed that a lot needs to be done for ICT to be effectively used in the environment, factors such as inadequate facilities, acceptance problem of and adaptation of technology, lack of awareness and illiteracy, mismanagement, lack of technical know-how and unstable internet service are challenges that should be looked at to leverage ICT in the environment. The study also noted the fact that ICT has affected the society and its environments in other negative ways such as the production of unwanted by-products called pollution and depletion of natural resources.
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Keywords: Environment, Technology, Globalisation

1. INTRODUCTION

Society has witnessed rapid changes in information technology (Aebischer, 2015). Every day individuals encounter technology at home, school and at work. Technology has the promise of a better world though the increase in productivity and enhancing a sustainable environment. Society as it is now is passing through different phases of sustainability problems thereby placing high expectations on ICT. According to *Höjer* et al (2015), ICT has an important part to play in

supporting sustainability strategies that will enhance the economy and in turn produce a better environment.

Studies carried out by various researchers and organizations have pointed to the fact that ICT will be able to make contributions to sustainable development and reduce environmental challenges in areas such as space, transportation, increase in efficiency of processes, etc. particularly in developing countries (GeSi, 2012; Mickoleit, 2010; Höjer, et al, 2015). These contributions will ultimately bring positive changes to the environment.

The word environment can be seen differently be different people. Some see it as a natural landscape or dwindling wildlife species (Kwazo et al., 2014), while some look at it as industrial pollution or threat to citizens' amenities caused by road constructions and building. Others according to Anil & Arnob (2001) consider it to be natural resources, land, energy, water and atmosphere. Environmental issues make better sense when one can understand them in the context of one's cognitive sphere. This means that the understanding of an environment is based on how an individual look at it with focus basically on its prospects and challenges.

There are multifarious environmental challenges faced by developing countries such as ecosystem deterioration, pollution, resource depletion, loss of biodiversity and climate change. (Martin, Maris & Simberloff, 2016; WEF, 2017; Voulvoulis & Burgman, 2019). According to Voulvoulis (2012), the management of these problems is difficult because they involve multiple actors and its occurrence is over time and space. Environmental Scientists have raised concerns on how these environmental challenges can be tackled bringing into lamplight, how ICT and environmental science research can be used to wedge these challenges in developing countries.

Infusing technology into the environment brings about the use of technological innovations to tackle environmental challenges. For instance, the use of photovoltaics, wind turbines etc can ensure sustainable development and promote sustainable management of resources. That notwithstanding, ICT has affected the society and its environs in other negative ways such as the production of unwanted by-products called pollution and depletion of natural resources. This paper intends to look at the impact of technology to the environment. The study will look at the strength and weaknesses of the use of technology in environmental activities and give recommendations on the best possible ways this can be coordinated in developing countries.

2. LITERATURE REVIEW

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2.1. Overview on the Concept of Environment

The word "environment" when considered from simple context can be defined as the entirety of the natural world in which we inhabit. Going by this definition alone will belittle the different variables and parameters that interplay to actually make up the physical environment. Taking into consideration the concept of the environment from a biological and ecological perspective, the word is coined from the French word environment which simply translates to surrounding(Harries, et al., 2004). From this it can be said is the living space and sum total of all external conditions that affects the development and survival of life on earth, the environment is made up of both living and non living components which can be classified as biotic and abiotic components in the context of human-environment factors such as religion, occupation, habits and culture are included as they affect the life of individuals. With this, the environment can be said to be of two categories:

2.1.1 The Physical Environment

This is the natural world around us made up of trees, rocks etc it can be further divided into four separate groups;

1) Lithosphere which is the solid components of the earth crust made up of rocks, mountains soil etc.
2) Hydrosphere which comprises of all water bodies, such as oceans, rivers, lake, sea etc.
3) Atmosphere which is the open-air enveloping the earth and comprises of gases such as oxygen, nitrogen hydrogen.
4) Biosphere which comprises of all living organisms, humans, animals microorganism etc.

2.1.2 The Cultural Environment

This comprises of man-made environment such as roads, railways, buildings, technological advances, political structures, religion and culture etc. The activities of the cultural environment is interwoven with the physical environment as ability to harness the physical resources of the later, lead to the creation of the former. Thus, the two environments greatly affect each other, although the effect of the cultural environment on the physical environment is considerably greater. This is maybe due to the fact that the concept of the environment is viewed differently by man and the concept varies depending on the society it is found.

2.2 The Environment in the Context of Developing Nations and Its Usage

Other than being the space that supports basic human living activities, the environment is viewed in terms of usage from a human perspective i.e. what it can be harnessed to do, what it has to offer, or what it can be transformed into to benefit man. As such, the understanding of the concept of the environment in

different society varies, as it is dependent on what the environment has to offer and the level of technological advances in such society. On a general note the environment is viewed as a source of economic development and growth, with the development of nation closely linked to the advantages or disadvantages of its surrounding(Cheung & Lo, 2018). This fact can be represented by an equation:

Development = Natural Resources + Capital + Labor (Cheung & Lo, 2018)

With what is stated above, understanding the context of the environment from the perspective of developing nations, one needs to focus on how the environment is engaged and linked in their economics activities. It goes without saying that these activities have their impact on the natural environment and leads to depletion of natural resources and capital. The next paragraphs highlight the use of environment in the economic activities of developing countries and the overall consequences of such activities on the environment.

One of the earliest forms of environmental use is the use land for agricultural purposes. This is the first step and indicator of industrialization of a nation as agricultural productivity in turns creates a boost in industrialization (Brahmasrene & Lee, 2017). Agricultural is a lucrative economic activity in developing countries primarily practiced in rural settlements. The agricultural productivity creates a synergy between rural and urban settlements in developing nation; rural resident supply agricultural products and the urban settlers bring about development of social amenities and manufactured products with an overall reduce cost in transaction (Richards & VanWey, 2015). Over time, land use for agriculture has increased to meet with the demand for food by the growing population in developing countries and also to tackle the issue of food security. This is reflective in the study conducted by (Hinz et al., 2020) in India which results revealed that increased number of lands will be lost by the year 2030 for crop and livestock production in order to meet with the growing population. The results further revealed a high emission CO2 to the atmosphere due to agricultural activities as well as loss in biodiversity. Furthermore, the consistent use of water bodies for irrigation practice is another cause of concern as this has resulted to some negative outcome. (Hamidov et al., 2016) in a review of agricultural impact in Central Asia reported increased level of secondary salinization of crop lands and water bodies, as well as desertification and soil degradation. All these overall generally lead to a decline in crop production in the long.

Another common land use in developing countries is exploitation of mineral resources in the form of mining. Mining is a process whereby of natural resources from the earth are obtained and processed into various useful finished products. Mining activities such as quarrying accounts as the major driving force of most developing nations economy and their products valued highly (Peter et al., 2018). The industry is a major employer in the region of Palestine with an investment

estimated of 700 million US$, and an annual contribution of 4.5% and 5.5% to the nation's gross national product and gross domestic profit respectively (Sayara, et al., 2016). The downside of this economic activity is the destruction of land forms and pollution of the atmosphere from the bye products of these activities. Studies conducted by (Peter et al., 2018) revealed a heavy loading of Particulate matter CO, NOx, SOx which resulted in air and water pollution as well as respiratory illness of individuals living in such environments. (Sayara, et al., 2016) reported similar findings in his study as results indicated pollution resulted in destruction of natural vegetation, loss of biodiversity, obstruction of crop yield and destruction of topography. Another similar study conducted in the of India revealed loading due to air pollution from coal mines (Dubey, et al., 2012) and underground water pollution from quarrying activities (Misra, 2013).

The major use of the environments experienced in developing countries is industrialization and urbanization. Urbanization is the influx of people from a rural background to an urban background primarily in search of better opportunities. It is projected that globally in 2050 more people will live in urban areas with 2 developing countries India and Nigeria and one developed country China accounting for up to 35% of that population (United Nations 2018; Kannan, *et al.,* 2020). This has led to developing countries building infrastructure and increase in productivity to meet with demand of shelter, relaxation, jobs etc. This is generally considered as evidence of economic growth and development but with consequences to the natural environment. (Kannan *et al.,* 2020) study revealed a general loss in agricultural lands, vegetation cover and water bodies due to increased urbanization and industrialization which may affect the food security of the region. This finding is similar to the study conducted by (Radwan, *et al.,* 2019) with results showing the loss of up to 74,600 hectares of land from the period of 1992 to 2015 and projections showing a possible loss of up to 86,900 hectares by 2030 with the current rate of urbanization. The study conducted by (Sarkodie, 2018) in 17 different developing African countries demonstrated the increase in level of environmental degradation due to increase in economic development and urbanization. This was attributed to increased level of food production, energy consumption, use of agricultural land to match the growing population. This ties closely to the study performed in Ethiopia by (Adem, et al., 2020) that revealed the loss of forest vegetation and biodiversity to create space for agricultural activities to match growing population. Another study reflects the effect of urbanization and the tourism industry in the developing countries of the south eastern part of Asia with results showing heavy loading of CO2 gas into atmosphere due to the energy and transportation demand of the sector (Brahmasrene & Lee, 2017).

The results of all these studies are an indication for the need of better environmental practices in developing nations when using the environment. As

such, better alternative options for constant planning and monitoring of the environment should be put in place.

2.3 The Role and Relationship of ICT in the Environment

With the many problems that are faced with urbanization, economic growth and globalization in developing countries, the need for a better method of practice which facilitates the growth and development of such nations while being sustainable is necessary. In recent times the trend in the rise of ICT has become evident and is almost an integral part of everyday live in the society. ICT is increasingly being recognized as a promising potential solution to tackle the issues of urbanization and sustainability such as management, proper planning and monitoring(Bibri, 2018b). With projections indicating that most people will live in an urban region in 2050, the need for smarter sustainable city is undeniable which can only be achieved through a holistic approach that involves formation of good policies coupled with the application of ICT. A smart sustainable city can be defined as incorporation and use of ICT in the operation of urban system to improve societal and economic life in a sustainable manner(Bibri, 2018a). In simpler terms is the use of ICT to improve the sustainability of an urban city. In recent times there have being a spark of interest in the achievement of a smart sustainable city, although most literature uses them interchangeably a sustainable city is not a smart city, and a city maybe smart and not sustainable. This is shown in the study conducted by (Yigitcanlar *et al.*, 2019) which showed that most current smart cities fail to meet criteria of sustainability that is progressive due high technocentricity policies, complex practices and ad-hoc conceptualization of notions. For an urban city to be really smart and sustainable an equal mix of ICT application and sustainable practices need to be adopted. For this to be achieved a lot of key players need to be involved as the field of smart sustainable cities is extremely interdisciplinary and transdisciplinary (Bibri, 2018a; Bibri & Krogstie, 2017) with disciplines such as urban and regional planning, urban design, data science, policy-making, modeling and simulation computer science, sustainability science, ecology, environmental planning etc (Bibri, 2018a). Importance of collaboration between key players in different field is highlighted in the case study involving the construction of a hospital in South Australia conducted by (Redwood, *et al.,* 2017). The synergy between these different fields makes it possible for ICT to be used to a tackle and monitor environmental issues. ICT is able to achieve this via urban computing and urban ICT; urban computing involves the use of data analytics and computational tools for proper urban planning using tools such as UbiComp, AmI, the IoT, and SenComp etc while urban ICT involves the use of ICT hardware and software such as RFID, GPS, infrared sensors, smart sensors, smart phones, internet infrastructure etc in daily socio-economic operation of an urban city(Bibri & Krogstie, 2017).

The role of relationship of ICT in the environment is still a developing field and as such, there are some potential issues that need to be addressed to ensure its success. (Lam and Ma, 2019) highlighted the probable issues to be encountered in the adoption of ICT such as risk information insecurity, personal privacy leakage, information islands, over-dependence on technology that may cause management issues and digital divide. All these can be caused by technical and non technical issues. Furthermore, the study indicated that these issues can be prevented by effort from different key players involved alongside adherence to cyber security standards and good security design.

2.4. Effects of ICT on the Environment; Strengths and Weaknesses

The role of ICT in environmental management and sustainability can never be overemphasized as displayed by its different applications. Although it is needless to say that everything has its pros and cons, the following paragraph highlights the positive and negative effect of ICT on the environment.

With increase in the level of agriculture to meet with the growing population, issues of environmental degradation due to poor agricultural practices and policy making have being on the rise. ICT has being pivotal in tackling such challenges. ICT has being used to facilitate labour, aid land management and land reforms, facilitate agricultural production and precision farming, insurance agricultural extension services etc (Daum, 2018). The efficiency of ICT application is demonstrated in the study involving the use of information system of irrigation facilities management using wireless sensor network (WSN) that utilizes radio frequency identification (RFID) and quick response (QR) code technology by (Nam *et al.,* 2017). This method improved level of water management and issues involved with traditional method of irrigation. Remote sensing and ICT satellites equipment have enabled Natural environmental management to be easier and more flexible. This has made it possible for analysis and prediction to be made about climate conditions, pollution level in atmosphere and studying of wave behaviour by environmental scientist via data collected. This application is reflected in the study involving detection of wave in the Mediterranean seas (De Leo, et al., 2020) and forecasting of air pollution load in cities(Cujia, *et al.,* 2019; Sharma, *et al,* 2018; Zhang *et al.,* 2018).

Furthermore, ICT application has being instrumental in urban city management processes. It has being able to increase efficiency while decreasing the amount of waste and bye-product involved in the process. Baptista, et al.(2012) demonstrated in a study that ICT application in transport reduced CO^2 emission, improved road safety and fosters eco friendly driving behaviour among road user. ICT potential in urban society management is yet to be fully realized as seen in research involving better method of water business processes using ICT (Ler, 2016) which identified gaps such as the need of integrated information system, the need of specific

functionalities in Asset Management, field work management, and other strategic domains and need of standard ontologies and asset description.

The display of the usefulness of ICT is best seen in how it is used in natural disaster management. This was observed in the role it played in the post-disaster recovery process of Great East Japan after being hit by what became known as the greatest earthquake in history(Cheng, *et al.*, 2015). ICT has now being adopted in disaster management, with its application used in four principle management steps; risk reduction, preparedness, response and recovery(Sakurai and Murayama, 2019). Further research are being conducted to ensure gaps are filled using approaches such as resilient communication, automated reporting, use of cyber-physical system such as drones for rescue etc. (Stute *et al.*, 2020).

With all the help the ICT has proven to be in environmental sustainability, it has also being linked to produce some harmful environmental issues. One of the major environmental issues associated with ICT is the environmental pollution generated from E-waste and its improper waste management. Most developed nations have resorted to shipping its used up ICT hardware to developing nations which in most cases lack proper method of recycling these products (Nganji and Brayshaw, 2010) this is seen in the study conducted by (Mmereki, et al., 2015) in the developing country of Botswana which highlighted the challenges faced in E-waste management. As stated by (Krumay & Brandtweiner, 2016) ICT affects the environment throughout its whole life cycle; from the mining of rare metals to produce ICT hardware down to its final disposal. This statement is support by study conducted by (Rothe, 2020) that highlighted the environmental pollution to soil and water in the production phase, the carbon footprint in the running operation of the sector, and production of toxic waste substances such as mercury, lead, cadmium during its disposal. Furthermore, the ICT sector is an ever-changing with regular updates, modification and improvement made, this is another problem in waste management as it demands quick adaptation to the ever-changing nature of E-waste produced (Olofsson and Mali, 2017).

The method of transmission of information by the ICT sector is made possible means of electromagnetic waves in form of radio waves or radio frequency. These radio waves have being attributed to be harmful not only to ecology but also injurious to human health as well. Studies such as the one conducted by (Balmori, 2016) reflect the negative effects of these waves from radio transmitters on animals such as reduction in survival and reproductively and the research conducted by (Bauer *et al.,* 2019) revealed the negative effects of heating of mobile phones on human health. There is still growing concerns of the effects of radio waves as the exposure rate seems to be on the increase with improvement in technology and increase in population. This is observed in the recent reception of the public to the introduction of the 5G mobile network technology. Although, most professionals argue that the effect of radio waves in most studies has not being

modeled under real-life conditions but mostly in controlled laboratory conditions, the study performed by (Kostoff, *et al.,* 2020) showing the effect of 5G network under real-life conditions revealed that the technology is toxic not just to skin and eyes, but has the potential to cause adverse systemic health issues.

When taking into context the overall effects of ICT on the environment, the good definitely outweighs the bad effects it comes with. Implementation of the practice of green IT which involves using more eco-friendly methods in the life cycle and running operation of ICT has be viewed as a possible solution(Krumay and Brandtweiner, 2016; Rothe, 2020)

3. METHODOLOGY

A quantitative approach using survey questionnaires was applied in the study. Survey questionnaires were used as an instrument of data collection to attain the goals and objectives of this research. The population for the study consists of different people from different developed and developing countries and their areas of specialization focused on ICT and Environmental studies. Google forms were used for the collection of data. The reason for using google forms is primarily to get a wider coverage. Links to the google forms were sent out through emails, WhatsApp, Telegram and Facebook since these social media are some of the most used platforms.

Specific countries were selected in other to give the study a global outlook. These countries include Turkey, Kenya, Singapore, UK, South Africa, Ghana, Canada, the USA, Australia, Zimbabwe, Nigeria, Cyprus and Nigeria. Furthermore, Areas of specialization of participants were also put into consideration. The participants were selected from the field of Information Technology, Geology, Ecology and Wildlife Conservation, Environmental Policy and Management, Biology, Environmental Physics, Environmental Science and Biomedical Sciences. The reason for selecting experts in this field is because the researchers feel that they will have a better understanding of the subject matter.

The expectation of the research in the area of data collection was a target of four thousand five hundred (4500) responses from the respondents. Data collected from surveys were analysed quantitatively using the Statistical Package for Social Sciences (SPSS), excel formats and were presented using graphs and charts.

4. RESULTS AND DISCUSSIONS

To understand the impact of ICT technology on the environment a detailed survey which is highly representative of different individuals involved in the field was conducted. The following paragraphs discusses the finding from the survey. The

first section gives a detailed description of the participants involved in the survey, while the second section shows the responses by the participants followed by discussion of findings. Three thousand seven hundred and eighty seven (3,053) responses were received as against the projected four thousand five hundred (4,500), which gives an acceptable percentage of 67.84.

4.1 Countries involved in the survey

A total of 13 countries were involved in the survey. The countries were systematically picked to be representative of opinions from different part of the world, with the major participants been developing nations from the African continent as this is the primary focus of the research. Nigeria had the highest number of respondents at 19%, this was followed by Ghana at a rate of 10.1% and Namibia closely followed at 8.3%. The USA had a response rate of 7.5% with Zimbabwe at 7%, Cyprus at 6.9% South Africa at 6.7%, the UK at 6.4%, Canada at 6.2% and Australia at 8%. The lowest response rate were obtained from Turkey at 5.7%, Singapore at 5.3% and Kenya at 5.1% respectively. Figure 1 below shows the graphical distribution of the respondents. The higher response rate is obtained from developing countries as they probably relate to the research and also because they feel it is important. This is better explained using the "leverage-saliency" theory of (Groves *et al.,* 2000), in his work he said individuals assign different weight or importance to surveys, considering the title of research it is most likely that individuals from developing countries will attach more importance to it.

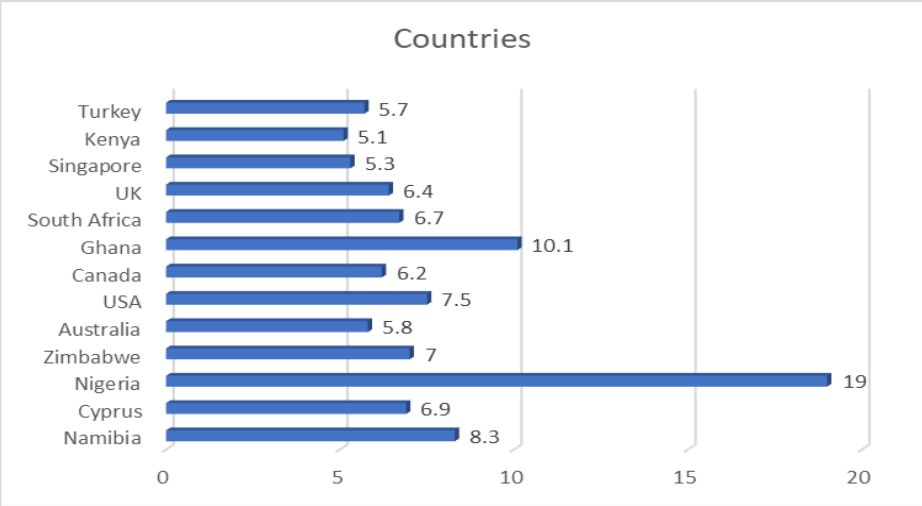

Fig 1*: Distribution of responses (Countries)*

4.2 Areas of specialization of Survey Participants

The figure 2 displays the different areas of specialization of respondents involved in the survey. The involvement of ICT in the environment is an interdisciplinary study and as such, different vital disciplines found to understand the impact of ICT on the environment were selected. Participants from eight (8) areas of specialization participated in the survey. Information Technology had the highest response rate at 19.4%, this was closely followed by Environmental Physics at a rate of 19% and Environmental Sciences at 18.6%. Environmental Policy and Management had a response rate of 10% while Biology, Ecology and Wildlife Conservation had a response rate of 9%. The lowest responses were observed in Geology and Biomedical at a response rate of 8% and 7% respectively. The observation from this result goes in line with the findings of (Saleh and Bista, 2017) and (Groves *et al.,* 2004), which states that individuals are much more responsive to survey topics that they can relate to.

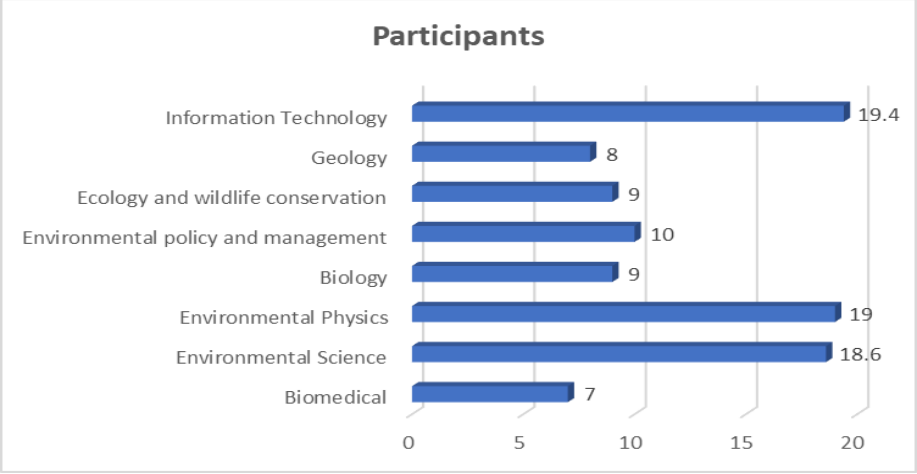

Fig 2*: Distribution of responses (disciplines)*

4.3 Age Ranges of Participants

The age of the different respondents that took part in the survey is represented in the pie chart in figure 3 below. The highest response rate was observed in participants between the age ranges of 26-35 at 72.20%. This was followed by participants between the age ranges of 18-25 at the rate of 22.20%. The lowest response rate was observed in participants within the age ranges of 35 and above at a rate of 5.6%. The outcome of this result goes in line with the work of (Watson & Wooden, 2009) which stated that older and younger members of a group are less likely to participate in a survey.

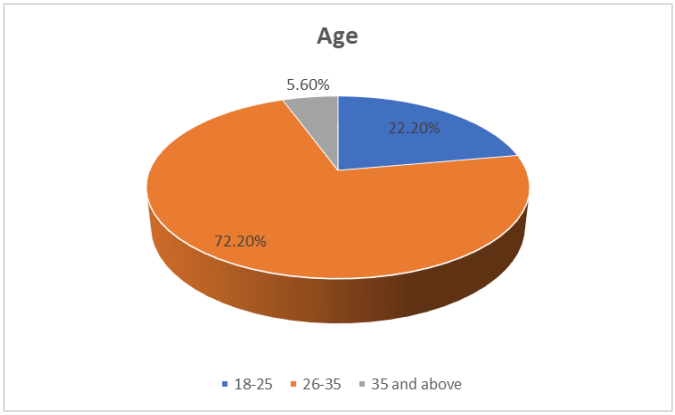

Fig 3*: Age Ranges of Participants*

4.4 Years of Experience of Participants

The years of experience of different respondents in their respective fields was also taken in to consideration, as this is a factor that has a major influence on the response of participants. As can be seen in figure 4, the highest response rate was observed among respondents with the age range of 11-20yrs at a rate of 55.1%, making this range the major respondents in the survey. This shows that the participants of the survey have relevant experience. Respondents within the range of 6-10 yrs had the second-highest response rate at 25.7%, this was followed by respondents within the range of 0-5yrs at the rate of 10.6%. The least observed response rate was from the experience ranges of 21yrs and above at a response rate of 8.6%. (Watson & Wooden, 2009) stated that people with higher experience and level of education tend to be more participative in surveys, so the results obtained here are indicative of this fact.

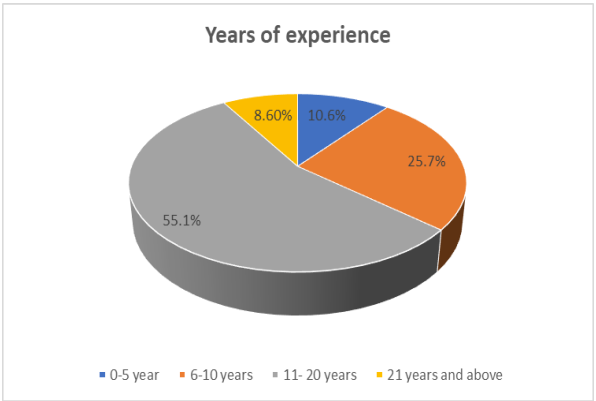

Fig 4*: Age Ranges of Participants*

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4.5 Level of ICT literacy of Respondents

The chat in figure 5 displays the ICT literacy of the participants of the survey. The result revealed a high number of the participants are ICT literate with a response rate of 88.1%. The response rate of participants involved that are not ICT literate was at 11.1% with the least response rate coming from participants who are not sure if they are ICT literate at a rate of 2.8%.

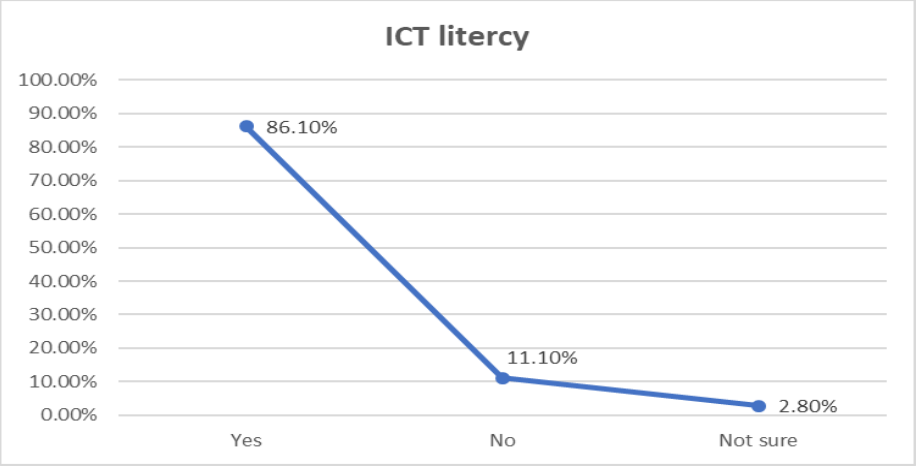

Fig 5*: ICT Literacy of Participant*

4.6 Is there a link between ICT and the environment?

All the respondents agreed that there is a link between ICT and the environment.

4.7 ICT Will Be Able to Make Sustainable Development and Reduce Environmental Challenges

As can be seen in figure 6, 55.6% of the participants involved in the survey agreed that ICT will be able to make sustainable development and reduce environmental challenges making it the highest response obtained, this was followed by 30.6% of the respondents who strongly agreed. 8.3% strongly disagreed with the statement while 5.5% of the participant disagreed with the statement-making it the lowest response rate.

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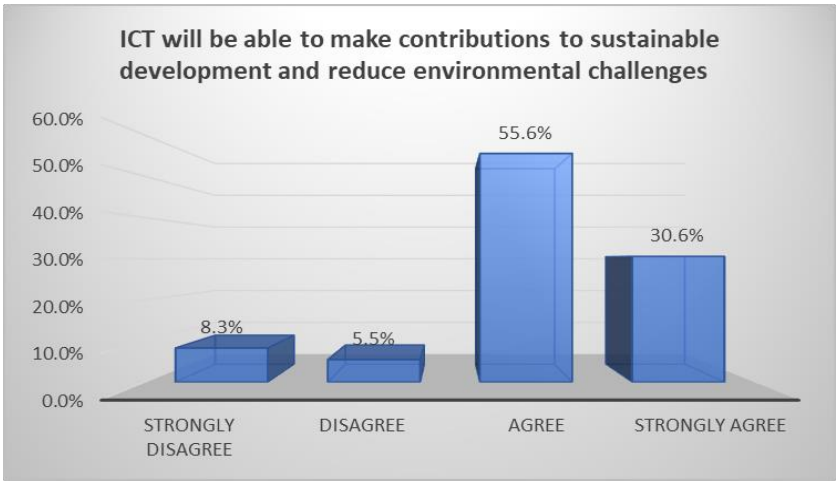

Fig 6: *ICT will be able to contribution and reduce environmental challenges.*

4.8 ICT and Environmental Sciences Research Can Be Used To Wedge These Challenges in Developing Countries

52.8% of participants in the survey agreed to this statement-making it the highest response rate, this was followed by 38.9% who strongly agreed to the statement. 5.2% of the participants strongly disagreed with the statement while the least response rate was from participants who maintained a neutral stance to the statement at 3.1%

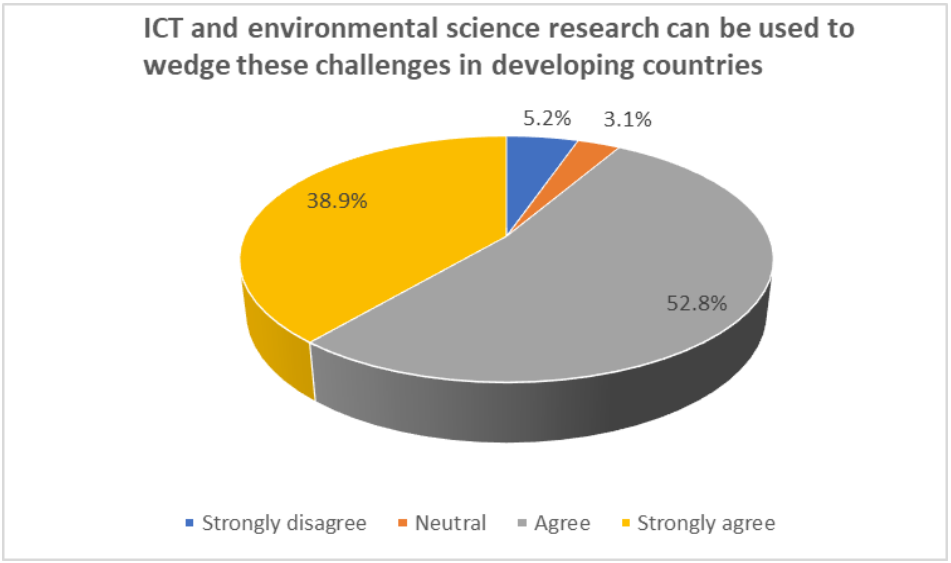

Fig 7: ICT and Environmental Sciences research can be able to wedge environmental challenges in developing countries

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4.9 ICT has affected the environment negatively via release of bye-products and depletion of natural resources

This statement proved to be controversial as majority of the respondents maintained a neutral opinion at 33.3%, this was followed by 25% of participants who agreed to the statement and 16.7% of participants who strongly agreed to the statement. 13. 9% of participants involved disagreed with the statement which was closely followed by 11.1% of the participants who strongly disagreed making it the least group in this category. This is displayed in the pie chart in figure 8.

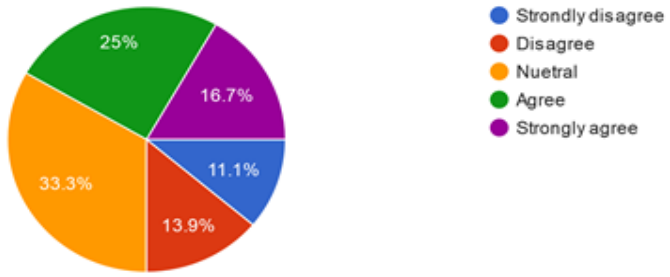

Fig 8*: ICT has affected the environment negatively via release of bye-products and depletion of natural resource*

4.10 ICT as a potential solution to urbanization and sustainability in developing countries

To this statement, 52.8% of the participants agreed, this was followed by 27.8% of participant that strongly agreed while the 14.2% maintained a neutral opinion to the statement. The least group in this category was observed in participants that disagreed with this statement at 5.2%.

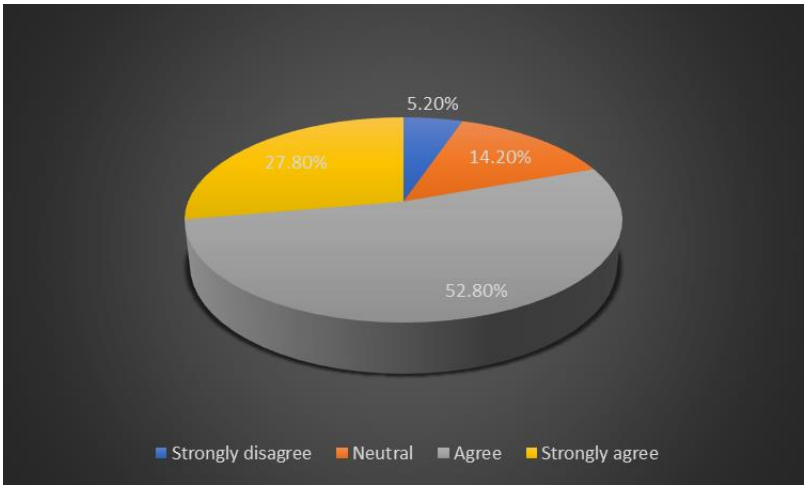

Fig 9*: ICT as a potential solution to urbanization and sustainability in developing countries*

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4.11 Security issues can be a challenge when ICT is used to tackle environmental challenges in developing countries.

Figure 10 below indicates that 44.4% of participants involved in the survey strongly agreed to the statement that security issues can be a challenge when ICT is used to tackle environmental challenges in developing countries making it the highest in the group, this was closely followed by participants who agree at 41.7%. Participants that were neutral were only at 8.9% and finally the least in this category was participants who disagreed at 5%.

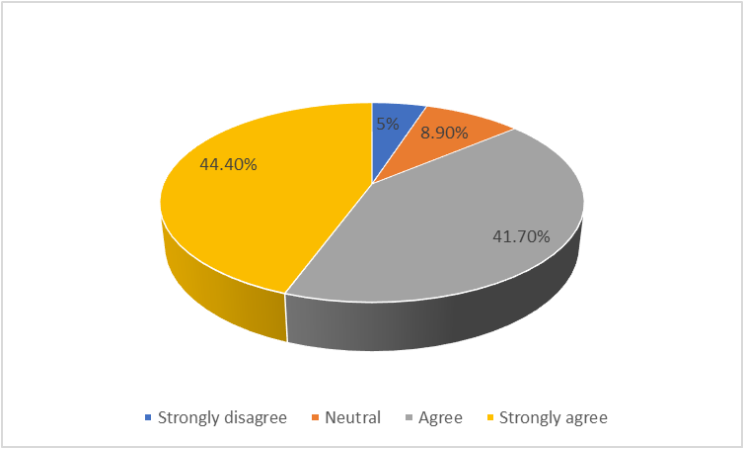

Fig 10*: Security issues will be a challenge when ICT is used to tackle environmental challenges in developing countries*

4.12 What other challenges do you think the use of ICT for environmental sustainability will face, particularly in developing countries?

To this question, the participants were given options of different probable challenges which are listed in table 1 below. Among the different options the highest picked was challenges associated with inadequacy of facilities at 25.1%, this was followed by problem of acceptance and adaptation of technology at 20.2%. 16.1% of participants picked the option of lack of awareness and illiteracy. This was closely followed by mismanagement at 15.2%, lack of technical know-how at 12.1% and finally unstable internet service at 11.3% respectively. This is displayed in table1.

Table 1: Challenges of using ICT in the environment

What other challenges do you think the use of ICT for environmental sustainability will face, particularly in developing countries	Responses
Problem of acceptance and adaptation	20.2%

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Inadequate facilities	25.1%
Unstable Internet	11.3%
Mismanagement	15.2%
Lack of technical knowhow	12.1%
Lack of awareness and illiteracy	16.1%

4.13 What are the recommended ways to tackle these challenges?

To this question, a set of options were offered to the participants to pick from which are listed in table 2 below. The highest option picked by participants as a probable solution to the challenges was making internet and ICT facilities available at 35.4%, this was followed by policy making at 23% this was followed by creating of awareness at 15.9%, training at 14.2% and finally increase level of literacy at 11.5% respectively.

Table 2: Tackling challenges

Recommend ways tackle these challenges	Responses
Creating Awareness	15.9%
Availability of Internet and ICT facilities	35.4%
Increase level of literacy	11.5%
Training	14.2%
Policies	23%

5. DISCUSSION OF FINDINGS AND RECOMMENDATIONS

The results obtained from the analysis above shows that a lot needs to be done for ICT to be effectively used in the environment. Not minding the fact that a large percentage of the respondents (88.1%.) indicated that they are ICT literate while all the respondents agreed that that there is a link between ICT and the environment, The respondents also noted that inadequate facilities, problem of acceptance and adaptation of technology, lack of awareness and illiteracy, mismanagement, lack of technical know-how and unstable internet service are challenges that should be looked at. Security issues were also noted as challenges when ICT is used to tackle environmental problems in developing countries. The respondent were also mindful of the fact that ICT has affected the society and its environs in other negative ways such as the production of unwanted by-products called pollution and depletion of natural resources

Not minding these challenges, over 80% of the respondents indicated that ICT will be able to enhance sustainable development and reduce environmental challenges. The respondents also noted that ICT is increasingly being recognized as a promising potential solution to tackle the issues of urbanization and

sustainability such as management, proper planning and monitoring in developing countries. They noted that for ICT to be effectively used to tackle environmental challenges, proper awareness should be created, adequate technology facilities should be put in place. Training should also be organised and policies that will enhance a secure environment for the adopting of ICT should be put in place.

6. CONCLUSION

Over the years ICT have made big contributions for the sustainable development and have caused a reduce environmental challenges in areas such as space, transportation, increase in efficiency of processes, etc. particularly in developing countries particularly in Africa, such contributions have ultimately brought positive changes to the environment. With the many problems that are faced with urbanization, economic growth and globalization in developing countries, the need for a better method of practice which facilitates the growth and development of such nations while being sustainable is necessary. In recent times the trend in the rise of ICT has become evident and is almost an integral part of everyday live in the society. ICT is increasingly being recognized as a promising potential solution to tackle the issues of urbanization and sustainability such as management, proper planning and monitoring. For ICT to be effectively used to tackle environmental challenges, proper awareness should be created, adequate technology facilities should be put in place. Training should also be organised and policies that will enhance a secure environment for the adopting of ICT should be put in place.

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