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Integrating Geo-information through Citizen Scientists, Sensors and Actuators: Opportunities and Challenges in the Lake Victoria Basin

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Abstract

Communicating information with location data is considered to be of higher value and informative. While data collected, processed and shared through citizen science, sensing and actuation is on increase, the quality has continuously been questioned. This paper identifies opportunities and challenges in engaging with wide spectrum of citizens in using geo-coding tools to increase the quality of data and effectively inform water resources sustainability. The study was conducted in Mwanza region, a potential area within the Lake Victoria Basin of Tanzania. Focusing on formal institutions of citizen engagement in irrigated lands in the study area, data were collected through questionnaires, key informant interviews and focus group discussions. Data were analysed using NVivo, Quantum GIS and IBM SPSS. Results indicated that the most prominent opportunities were the presence of substantial number of semi-literate and literate persons of age most active in citizen engagement programs and increasing utilisation of renewable sources of energy especially solar energy. The most prominent challenges were inadequate ownership and access to ICT devices that support geo-coding, inadequate access to grid electricity and poor rural mobile network to support usability of devices. Discussion of results was based on the characteristics of citizen engagement of inclusivity, transparency, breadth of coverage, depth of coverage, passion, scope, scale and relevance. The study concludes that despite presence of geo-coding platform that can engage wider public in managing their water resources in the Lake Victoria Basin, there are more challenges than opportunities to realise this goal.

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1. Introduction

Declining water resources at the time of increasing demand is one of the global environmental concerns of the 21st Century. Among the priority efforts to tackle these kind of environmental challenges is informed citizen engagement (Follett & Strezov, 2015). Altschuler and Corrales (2013) argue that enabling the environment for high-level engagement with citizens includes adequate accessible and useful technology, full functioning social system and favourable political climate. Informed engagement through citizen participation as passive researchers is termed "citizen science" (Follett & Strezov, 2015). Citizen Science is often described as a research technique whereby citizens have to actively contribute to science either with their intellectual effort, or surrounding knowledge, or their tools and resources (European Union (EU), 2013; Bonney *et al.*, 2009). Other forms of citizen engagement such as citizen sensing and citizen actuation are emerging and becoming popular. Citizen sensing is a form of citizen engagement where volunteers (citizen sensors) collect information from social media and make them available for the wider audience including the dissemination and creating awareness (Rose *et al.,* 2005). Citizen actuation is a form of citizen engagement where a volunteer (citizen actuator) takes action in case of communication that requires a solution. The action could be reporting the matter to a law enforcing organ, correcting the problem that is within reach, taking measures to prevent a possible conflict such as organising a negotiation process, leading a mediation process or facilitating the litigation process. It could also be an action leading to a new policy, regulation or just a rational decision.

Information tied to the location is attributed to be value-added and more informative. Modern Information and Communication Technology (ICT) provides tools that may support information with geo-tag. For example, using tools capable of providing location data increases the value of communicating data and information. Geo-coding is one of the geo-informing processes whereby tags are added to an information file such as text, image, voice or even video using devices such as Geographic Positioning System (GPS), geo-code enabled Smartphone, online geo-coding tools, camera and sensors. Some tools are integrated with GPS thereby providing automatic recording of location data. Automatic geo-coding reduces transcription errors while enabling verification (Pecl *et al.*, 2015).

The landscape of computing technology is rapidly changing as to include new hardware and software tools that support an array of activities. On technology, mobile hardware and apps collectively provide collaborative and social computing opportunity for skilled and semi-skilled personnel. According to recent data, the number of mobile phone users globally hit 5.07 billion in 2019 (Statista, 2020). Global System for Mobile Communications (GSMA) shows that in Africa there were 456 million users at penetration rate of 44% (GSMA, 2019a). In Tanzania, The World Bank (WB) estimates that there are 77 mobile phone subscribers in every 100 people (WB, 2019). Further to these records, generic reports show that internet coverage, especially in low-income countries, is increasing whereby mobile network complements wired internet infrastructure (Statista, 2020, Taylor and Laura 2019, GSMA, 2019a, GSMA, 2019b, GSMA, 2018). Penetration rates of mobile networks both in rural and urban areas and the constantly improving enabling environment by policies and regulations have been demonstrated. Enhanced internet access means also the availability of associated communication services such as Voice over Internet Protocol (VoIP), access to social networks, e-mails, photo sharing, video sharing and access to community radio over IP. Availability of devices capable of geo-coding such as smart phones, tablets and palmtops is also on positive trends. Newman *et al.,* (2012) mention the surprising trends of mobile telephony in the world, singling out the magnificent transformation in developing countries and the better future they are likely to bring with an active participation of citizens.

Integrating the tools in the wake of improving geo-information would arguably be resource efficiency and citizen engaging option. Integrating geo-coding tools would support citizen engagement in multiple disciplines, using different devices but with the same collection and processing point. They also serve as a gateway for the dissemination of resultant information that builds awareness or triggers further actions. The same platform can host stakeholders at multiple levels thereby enhancing coordination roles. The World Bank Group (WBG) in its 2016 World Development report focused on “Digital Dividends” (World Bank Group, 2016). Apart from coordination, the platform can as well contribute to the expected “digital dividend” to a wider community and future generation. The same report acknowledges that digital technologies are doing some wonders in transforming economies and societies. The report further indicated that 8 out of 10 people in the developing world own a mobile phone. The worldwide statistics for internet penetration in developing countries is 58.7% (4.574 billion people) (Internet World Stats, 2020). However, such contribution has not tallied with the rapid advancement of technologies especially with empowering the citizens and elimination of associated institutional constraints.

Data and information collected through citizen-based initiatives such as through citizen science, citizen sensors and citizen actuation have repeatedly been questioned over their correctness and reliability (Nature Editorial, 2015; Follett & Strezov, 2015; Pecl et al. 2015). For example, data collected by citizen scientists are sometimes considered of poor quality, misleading or even malicious (Anhalt-Depiesa, et al, 2019). Quality of citizen science data is measured by multiple dimensions including accuracy, completeness, consistency and timeliness. Manually collected data is prone to human error that may propagate through the process of collection, processing and delivery of final information. Extant research has proposed how ICT can provide tools that improve the quality of data collected by citizen scientists. Golbeck (2009) suggested social tagging sites as one of the techniques to enhance trust. However, according to Alabri (2014), there has been little or no previous research undertaken into using these in improving the quality and reliability of citizen science data. Brofeldt *et al.* (2018) studied the involvement of community in using ICT-based system to monitor the forest. Their study reported that there was increase in quantity of data collected irrespective of age and gender of the community members. The study reports further that for each set of 100 data entries only 42.1% was validated (Brofeldt *et al.,* 2018). There is, therefore, a need for furthering interventions to improve the research process involving the citizen science. While geo-coding tools are increasingly being integrated into systems using modern devices such as sensors, smart phones and web-based tools, their effective use by members of the public in developing countries is low.

In addressing some of the issues related to collection, processing and sharing of data for water resources management, a team of researchers has developed an integrated Water resource Governance System (WaGoSy) specifically tailored for use in the Lake Victoria Basin (LVB) (Faustine *et al*., 2014; Mongi *et al*., 2015; Mvuma *et al*, 2014). The main research output was Water Resource Governance System (WaGoSy), an integrated ICT solution for addressing governance challenges related to LVB water resources (Mvuma *et al*, 2014). The system comprises the following integrated components or modules: Web-Based Portal (WaGoSy-WBP), Water Quality Reporter (WaGoSy-WQR), Wireless Sensor Network (WaGoSy-WSN), Open Meeting (WaGoSy-OM), Visualisations (WaGoSy-V) and SMS Box (WaGoSY-SMSB). Most of these solutions involve geo-data. With this system, citizens are both producers and consumers of data and information generated. This paper draws from WaGoSy, an integrated ICT platform that was developed and tested in the LVB. This study utilises the system-user view approach in rural, peri-urban and urban contexts of developing country to: (i) review how the existing WaGoSy architecture can support citizen engagement geo-informing activities, and (ii) evaluate users' perceptions of opportunities and challenges of geo-coding within the framework of WaGoSy. In this paper, it is argued that the existing architecture of WaGoSy provides for geo-informing functionalities where activities done by citizen scientists can easily be located, shared and followed-up. The next sections of this paper detail the methodology followed, results and discussions as well as conclusion.

2. Methodology

2.1. Description of study area

The study was conducted in LVB portion of Tanzania. The criteria for selection of the study area were the presence of water resources of significant size, formal institutions for utilization of water for agriculture at small and medium scales, and challenges amounting to classification of such sites as "hotspots". LVB has a dual description. First, based on its largest water resources, it is an independent lake basin shared by Tanzania, Kenya, Uganda, Rwanda and Burundi (Figure 1). According to Lake Victoria Basin Commission (LVBC), shares of LVB's 194,000 km^2 for each country are 44%, 22%, 16%, 11%, and 7%, respectively (LVBC, 2015). Second, LVB contains Lake Victoria, the second largest lake in the world with an area of 68,800 km^2 (ibid). Lake Victoria is a source of River Nile making LVB a sub-basin within the Nile River Basin (NRB). NRB occurs in many more riparian countries than LVB amounting to 11 as of the year 2020. These are: Burundi, DR Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, The Sudan, Tanzania, Uganda, and Egypt. In Tanzania, the study was conducted in Mwanza, because the region and especially the City of Mwanza is fast growing in terms of human population, industrial as well as agricultural activities which have implications for water resources.

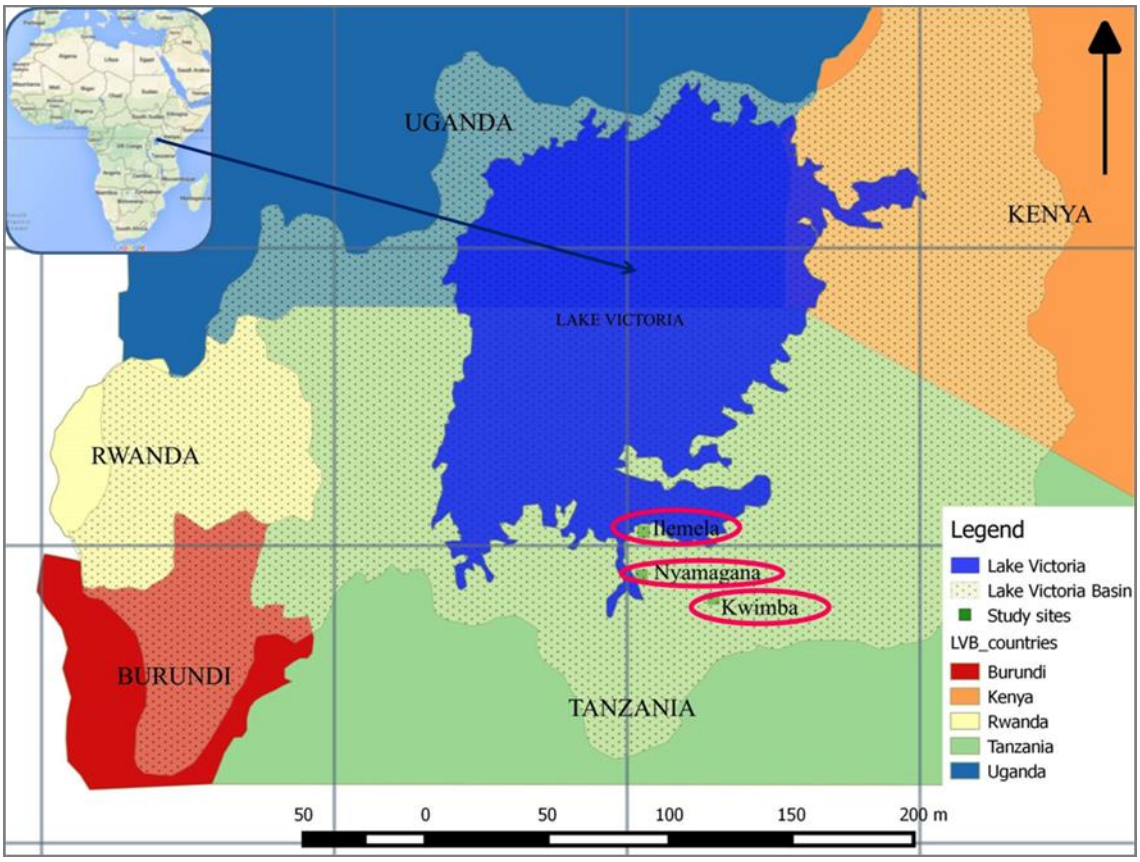

Figure 1: Map of LVB showing the location of study sites in Tanzania (Source: Authors' creation with Google Maps)

Users were selected from three districts namely Ilemela, Nyamagana and Kwimba from urban, peri-urban and rural contexts of Lake Victoria Basin respectively (see Figure 1). One ward from each district was selected. Selected wards from each district were Buswelu, Lwanhima and Mwanghalanga, respectively. Selection criteria included the presence of formalised irrigation organisations, the extent of marginalisation of participants (judged by access to basic infrastructure and services), and willingness to participate in the study.

2.2. Review of existing systems' architecture

The components of the existing system (WaGoSy) were reviewed in order to identify options supporting citizen engagement in the forms of citizen science, citizen sensing and citizen actuation. The existing overall architecture of the WaGoSy consists of sensors which can capture and send water quality data to the central database via mobile phones (Figure 2). The general public with access to mobile phones and the internet are able to comment, share, receive and report water governance issues in their localities through the system. It also has a mechanism whereby community radios can interact with the community to share and discuss various issues related to water resources through mobile phone messages. Finally, it has the mechanism which enables management (policy makers, decision makers and law enforcers) to view different kinds of reports and receive appropriate information and feedback on issues relating to water resources governance for appropriate action through the mobile phone, emails and web access.

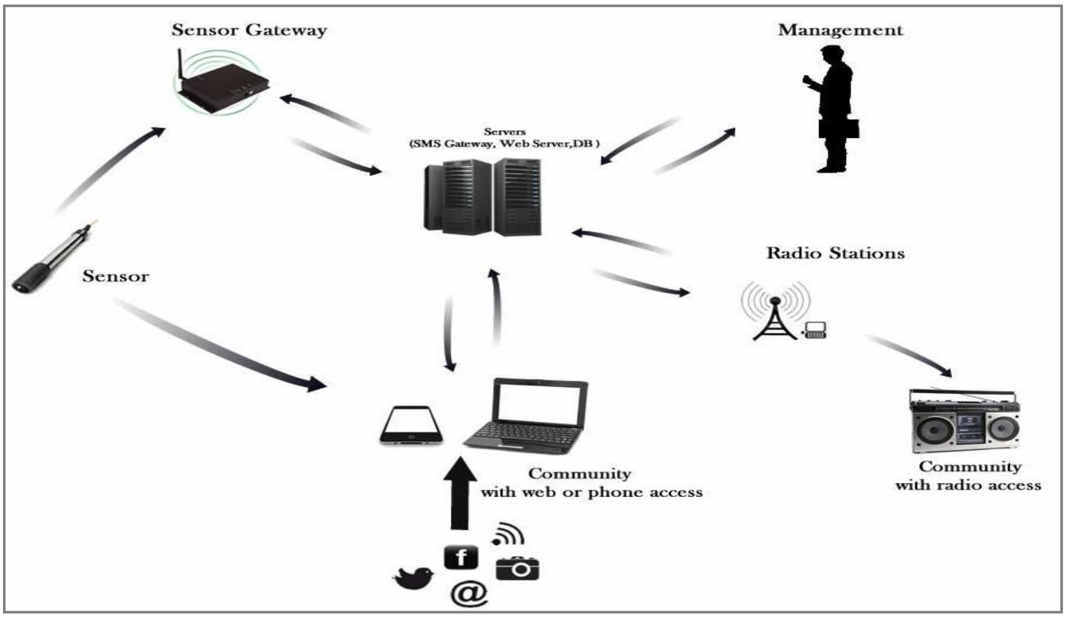

Figure 2: Existing generic architecture of WaGoSy
Source: Faustine, *et al*., (2014).

2.3. Evaluating user's views on opportunities and challenges

The study adopted the descriptive/exploratory design with mixed-methods combining both qualitative and quantitative methods in a longitudinal approach to data collection. This approach allows sequential implementation of the mixed methods. In this approach, the qualitative (QUAL) was sequentially followed by the quantitative (QUAN) paradigm. It is argued that sequential approach does not necessarily attach equal weight to methods from each of the QUAL and QUAN paradigms. Building on this argument, methods from QUAL paradigm such as focus-group discussion and key informant interviews were implemented first, followed by QUAN methods including questionnaire administration.

2.3.1. Qualitative data collection and analysis

Qualitative primary data were collected through Focus-Group Discussions (FDGs) which were held prior to survey instrumentation. Focus-Group Discussions (FDGs) were held prior to survey instrumentation. Group size of between 12 and 15 individuals were selected at random for each village/street with keen interest in gender participation. Both narrative inquiry and action research strategies were employed. This in-depth acquisition of information on the local perceptions and ideas pertaining to the mentioned cross-cutting issues contributed to validation of both ICT criteria and sustainability indicators. Both narrative inquiry and action research strategies were employed. This in-depth acquisition of information on the local perceptions and ideas pertaining to the mentioned cross-cutting issues contributed to validation of both ICT criteria and sustainability indicators.

Key informant interviews (KIIs) were conducted in the study area for the purpose of getting insights into criteria and social elements of integrated ICT solutions. Semi-structured and unstructured interviews were conducted with selected local individuals, radio presenters, water quality data managers, and water-basin managers. The data collected contributed to the understanding of the usability of the systems as well as the relevance of their components in addressing sustainability of water resources. Personal field observations were made on the realities of social processes that exist in the study area to establish the capacity of the locals to engage in water resources management using ICTs.

Qualitative data obtained through open-ended questions, unstructured interviews, and focus group discussions were analysed using NVivo Package. The package is a strong analytical tool for qualitative data. The following procedures were applied: (i) summarization of repetitive issues; (ii) identification of key thematic issues; and (iii) identification of strength of key thematic issues.

2.3.2. Quantitative data collection and analysis

Quantitative data were collected mainly using closed-ended questionnaire complemented with secondary data from the literature. The sampling technique was purposive random sampling as suggested in Kothari (2010). One ward was purposely selected from each district. Selection criteria were based on the criteria mentioned in section 2.1. Sampling frame was small-scale irrigators of the selected wards in the three districts. Their population was estimated at 720. The sample size was determined by using the following formula with suggestions from Chen and Popovich (2002), Krzanowski (2007), Kothari (2010) and Ryan (2013):

$$n = \frac{pZ^2}{Z^2 - 4e^2(1-p)} \quad (1)$$

Whereby:

n = estimated sample size

z = a number relating to the degree of confidence to be envisaged in the result.

e = the desired level of precision (standard error)

p = Population from which the sample will be drawn

Substituting the values of Z=1.96, e = 0.05 (or 5%) and p = 720 into equation one (1) above we obtain a sample size (n) = 251 participants. The distribution of sample size by districts was Ilemela (91), Nyamagana (89) and Kwimba (71). Closed-ended questions were coded and analyzed as quantitative data using IBM Statistical Package for Social Sciences (SPSS) and Quantum Geographic Information Systems (QGIS) based statistical tools. Descriptive analyses such as frequency, scatter plots and cross-tabulations were used and the applicable goodness of fit for the categorical data was determined by Person's Chi-square (χ^2) indicated in equation (2):

$$\chi^2 = \Sigma \frac{(Observedvalue - Expectedvalue)^2}{Expectedvalue} \quad (2)$$

3. Results and discussion

3.1. Reviewed WaGoSy as Integrated Geo-informing Platform

Analysis of existing system components with a view of citizen engagement options produced a customised WaGoSy architecture, simplified to illustrate options for volunteer engagement as citizen scientists, citizen sensors and citizen actuators. System-oriented and users' oriented view of opportunities and challenges helps to determine the likelihood of the system to meet users' needs. In the context of Lake Victoria Basin and particularly among small-scale irrigators in the study area, their basic need is the sustainable availability of water. For every drop of fresh water available, about 70% is used for agriculture (World Bank Group, 2014). Therefore, to ensure water is sustained, its challenges should be addressed mainly by communities who know them and probably can work with scientists, policy makers and decision makers to find and implement the solutions.

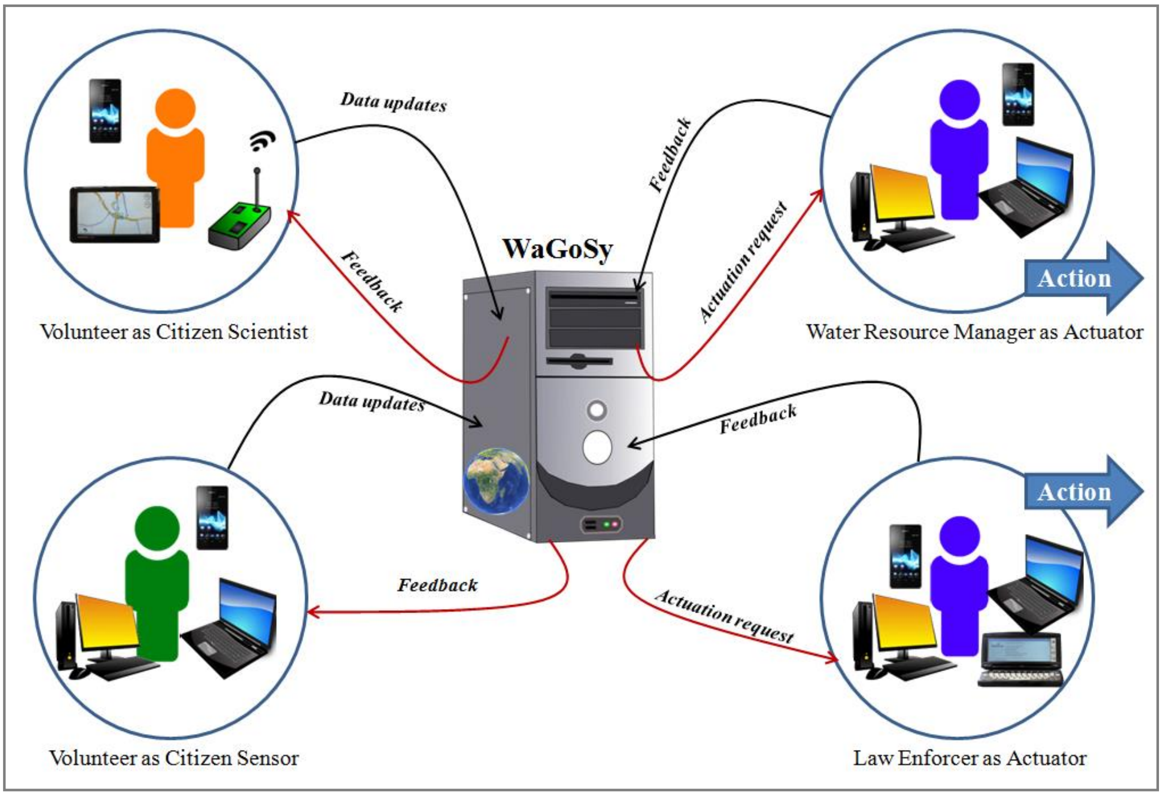

Figure 3: Customised WaGoSy architecture showing engagement options

Customised WaGoSy provides the much-needed environment for data collection, processing, storage and dissemination. Therefore, it supports functions of citizen scientists, sensors and actuators. In other words, the presence of the system customized to accommodate citizen engagement for water resources sustainability is one of the opportunities to address water-related challenges at individual and community levels (Figure 3). For example, according to a report produced by United Republic of Tanzania (URT) irrigation communities include irrigation organisations, Community-based Organizations (CBOs) and farmers/irrigators (URT, 2002).

All these can constitute potential volunteers as citizen scientists, citizen sensors or actuators. Furthermore, they are expected to perform tasks such as development and improvement of the irrigation scheme, collect and manage irrigation service charges, operate and maintain irrigation infrastructure, establish irrigation database and link up with the national database and to coordinate support to irrigators and organisations in irrigation interventions. Therefore, any citizen scientist, sensor or actuators from the referred community is expected to work within this framework. Apart from supporting the development of irrigation database, WaGoSy can support other research and practice data and information for other activities.

The most important thing to note about the system is its flexibility with regards to the type of users. Citizen scientists can also be citizen sensor or actuator depending on the role played in the process of data gathering and sharing. Some factors favour users to achieve their roles and receive their “digital dividends” (WorldBank Group, 2016). Organised citizen scientists in well-formalized institutions in the study area (Mongi & Mvuma, 2015) would contribute to achieving sustainability of water resource. Education levels across geographic locations provide the opportunity of engaging volunteers as citizen scientists, citizen actuators and citizen sensors. This in turn creates inclusive evidence-based and action-based community of practice. Integration of citizen sensors and geo-coding capability and geo-coded information creates evidence-based inclusive geo-data and geo-information needed to deliver the roles mentioned in URT (2002). Consequently, creates informed processes of policy formulation, decision making and rapid responses.

Customised architecture places the citizen engagement options at the periphery of the central database. Community volunteers who work with mainstream scientists as collaborators (citizen scientists) can use devices available at their disposal such as mobile wireless sensors, smartphones (high-end mobile phones) or on other phone capable of geo-coding with external GPS to collect data on issues related to water resources management at their places. Such data are then sent to the central database of the WaGoSy. Community volunteers who mainly post issues regarding water resources using social media (citizen sensors) can also submit their entries with geo-data tagged by the devices they use such as laptops, desktops or smartphones to the central database. Data and information on the central database can be available to Citizen Members responsible for taking action (Citizen Actuators). Such data or information can either be solicited or non-solicited. The former means data or information is available upon request by actuators in which case acknowledgement of receipt and action are demanded by the sender (Central system). The latter means data or information is sent automatically to the Actuator upon meeting some certain urgency criteria. Such criteria may include reports associated with star ranking of urgency, data received that indicate certain pre-set thresholds have been exceeded (example for water quality), or those indicating a signal of fatal conflict.

3.2. User's characteristics

Results showed that 36.21% and 63.79% of 251 participants were females and males respectively. Participants (here referred to as potential WaGoSy users) came from various backgrounds and organisations engaged either directly or indirectly in water resource governance as depicted in Figure 4.

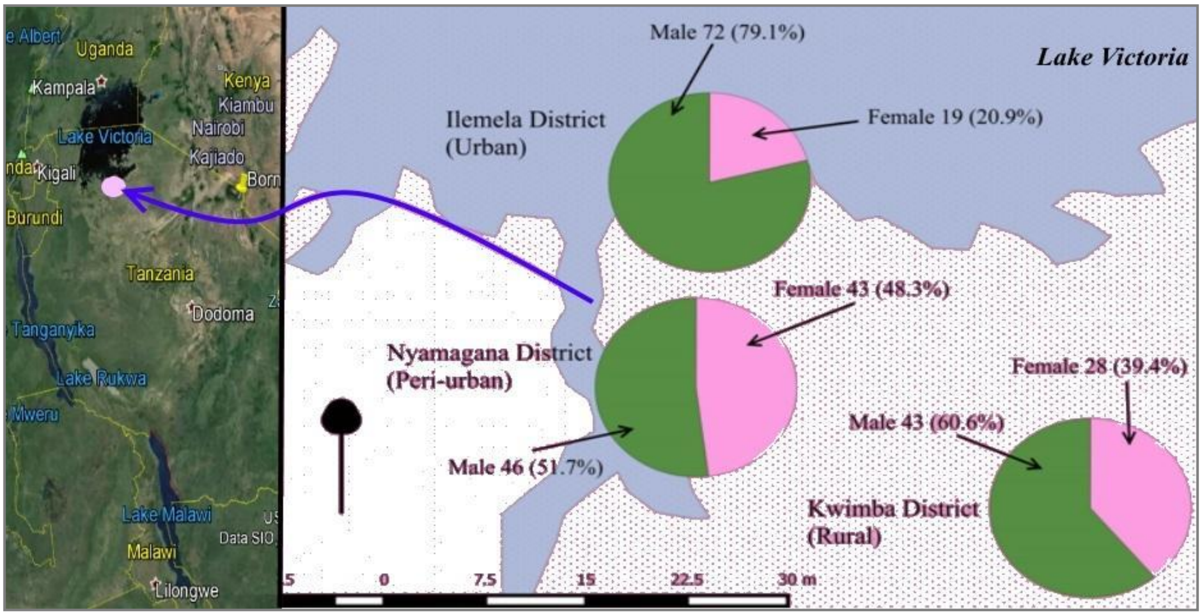

Figure 4: Participants' geographical area by sex

Source: Field data and Google maps

Table 1 summarizes participants by their geographical location and age category. Except for rural areas where persons of age category 36-50 years seemed to dominate by 46.48% (N=33), the rest of the geographic areas were dominated by age category 20 – 35 years by 62.64% (N=57) and by 42.70% (N=38) for urban and peri-urban areas respectively.

Table 1: Summary geographical distribution of participants by age category

Geographic location	Age category in years (*n, %ge*)			
	20 - 35	***36-50***	***Above 50 years***	***Total***
Urban	57 62.64%	23 25.27%	11 12.09%	91 100.00%
Peri-urban	38 42.70%	32 35.96%	19 21.35%	89 100.00%
Rural	28 39.44%	33 46.48%	10 14.08%	71 100.00%
Total	123 49.00%	88 35.06%	40 15.94%	251 100.00%

Place of birth indicated immigration/emigration status of the participants thereby some degree of "imported" experience into the new area. Peri-urban areas showed anomalies whereby natives were fewer compared with the rest of geographic areas (Figure 5). As expected, there was the least number of guests in rural areas compared to urban and peri-urban areas.

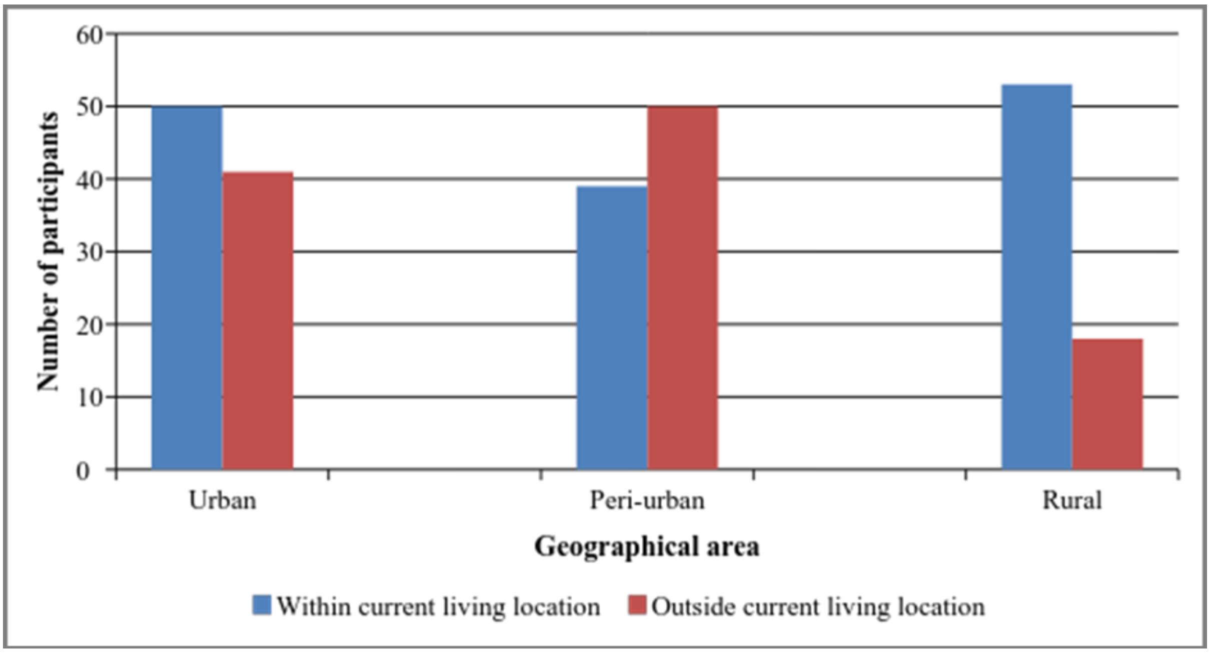

Figure 5: Summary geographical distribution of participants by their place of birth

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Usually the longer the duration of stay in the same place the more experience accumulated about the environment including water and related resources. Duration in which participants have stayed in their geographical locations is shown in Table 2.

Table 2: Participants by the length of stay in their geographic areas

Geographic area	Interval length of stay in years (*n*, %ge)					
	1-5	***6-10***	***11-15***	***16-30***	***Over 30***	**Total**
Urban	21 23.08%	6 6.59%	5 5.49%	25 27.47%	34 37.36%	91 ***100.00%***
Peri-urban	13 14.61%	4 4.49%	5 5.62%	30 33.71%	37 41.57%	***89*** ***100.00%***
Rural	2 2.82%	4 5.63%	2 2.82%	27 38.03%	36 50.70%	***71*** ***100.00%***
Total	36 14.34%	14 5.58%	12 4.78%	82 32.67%	107 42.63%	**251** **100.00%**

2-tail Chi-square statistic value = 15.68; significant 0.047*

Findings show that 42.63% (N=107) of participants across geographical locations had stayed in their places for more than 30 consecutive years. On place by place basis rural area was leading by 50.70% (N=36) followed by peri-urban by 41.57% (N=37) and urban areas by 37.36% (N=34). Over 75% (N=189) of all participants (N=251) had stayed in their places for sixteen (16) or more years. Geo-coding is a modern technological solution that knowledge of a place acquired through experience is a value addition. A study by Brofeldt et al (2018) indicated that the amount of data collected was independent of age and gender. However, the choice between what to report as a change in water resources requires past knowledge of the location.

3.3. Participants' views on Geo-informing opportunities and challenges

Participants (users) views are presented as either external factors likely to promote citizen engagement with geo-coding of water-related data (opportunities) or as factors likely to demote the same (challenges). Results indicate that a factor can be a challenge in a certain geographical location, say, rural area and at the same time an opportunity in a different area. Therefore, opportunities and challenges are presented together and described where necessary.

3.3.1. Ownership of devices

Mobile devices capable of geo-coding (for example, smart phones) are relatively more expensive than incapable ones. Results also indicated perceived high costs of devices that support geo-coding with consistency across geographical locations (Table 3). In rural, peri-urban and rural areas, 60.61%, 73.24% and 72.06% of participants perceived, in a respective manner, that the costs of devices were high and therefore limiting their ownership. Furthermore, the findings show that low-end mobile phones (those providing basic access services) were among ICT devices owned by the majority of participants

Table 3: Ownership of mobile devices by area, age, sex and education levels

Category	Description	Mobile ownership (n)	Percent age	Chi-square value and significance
Geographical area	Urban	78	85.71%	
	Peri-urban	57	64.04%	12.03, 0.002*
	Rural	56	78.87%	
Age	Youth	100	52.36%	
	Middle age	65	34.03%	4.78, 0.092ns
	Elder	26	13.61%	
Sex	Male	137	71.73%	22.03, 0.000***
	Female	54	28.27%	
Education	Primary education	119	62.30%	
	Secondary education	25	13.09%	
	Post-secondary education	39	20.42%	33.67, 0.000***
	Adult education	1	0.52%	
	None (illiterate)	7	3.66%	

ns Means not significant; ***, **, * Means significant at 0.001, 0.01 and 0.05 respectively

Mobile phone ownership by geographical location was dominated by urban area with 85.71 (N=78); as for age it was dominated by youth by 52.36% (N=100); by sex it was dominated by male by 71.73% (N=137); while by education was dominated by primary school leavers by 62.3% (N=119). Although this is good for massive collection and sharing of simple information, they may not support direct geo-coding hence a challenge to wider citizen engagement with geo-code. Relatively big number of primary school leavers with mobile phones may indicate the need for intensive user education especially when recording video and audio information is needed. World

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Bank Group (2016) indicated that 8 out of 10 people in the developing world owned a mobile phone. Mobile phone ownership in the study area was nearly equal to this observation.

3.3.2. Accessibility to energy

Access to stable energy is needed in order to ensure smooth operation of the geo-coding devices as well as citizen engagement with WaGoSy. The findings indicated diverse access to energy in urban, peri-urban and rural areas. For example, main sources of energy for urban areas were the solar panel (N=52) and grid electricity (N=24). For peri-urban areas, the main source of energy was fuel generators (N=41), while for rural areas was dry cells (Figure 6).

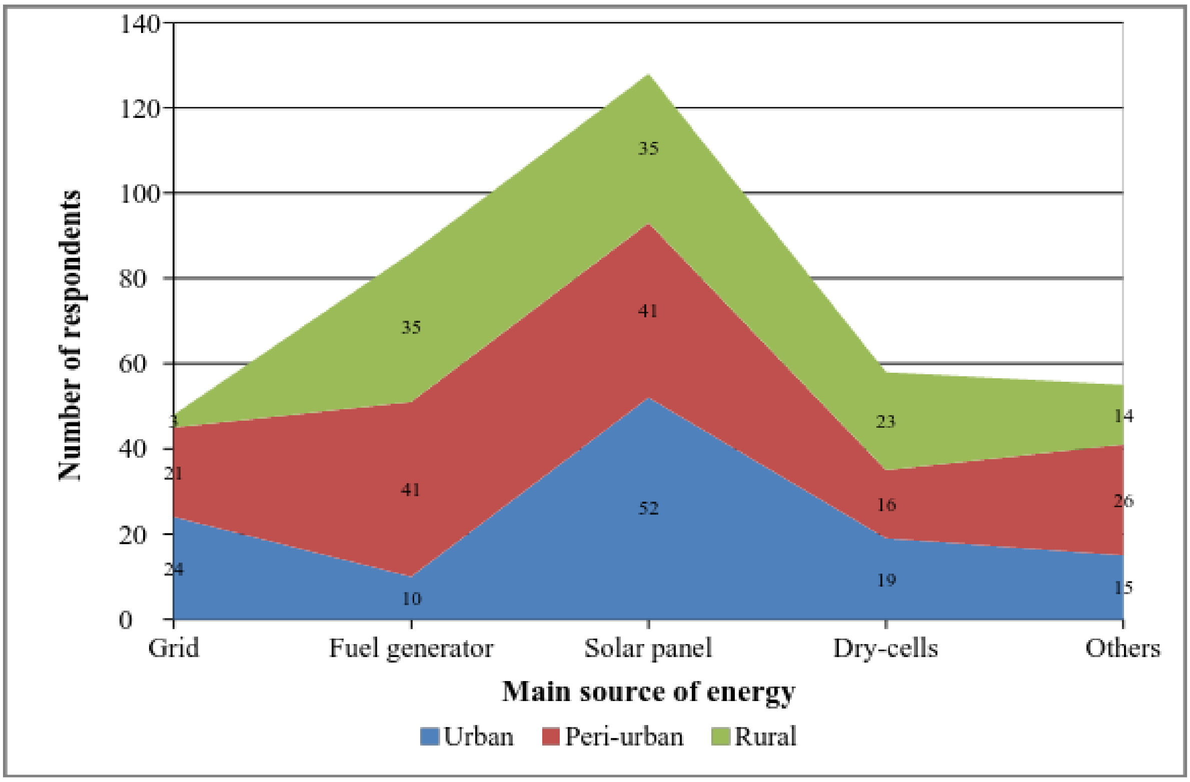

Figure 6: Main source of electric energy

Utilization of solar energy to power devices capable of geo-coding is increasingly becoming the opportunity in all geographic areas. However, accessibility to grid electricity seemed a challenge mainly in rural areas.

3.3.3. Accessibility to mobile network

Accessibility to the network to support SMS, data and voice communication is essentially important for smooth operation of WaGoSy and the connected public. Results indicated that nearly 70% (N=176) of participants in all three research sites perceived the network coverage to be in the range of moderate to low (Figure 7).

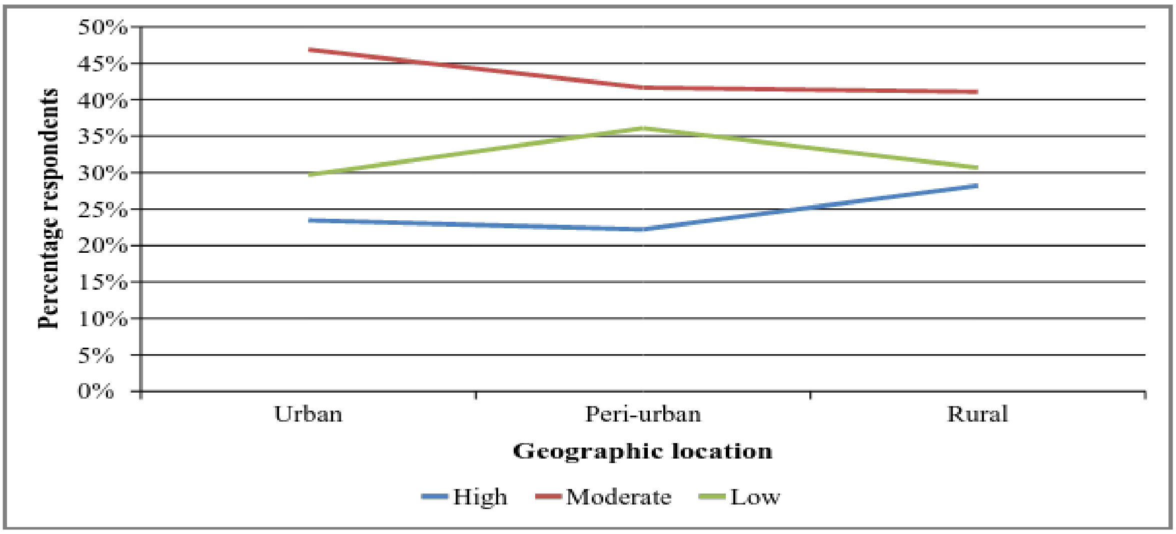

Figure 7: Perception of mobile network coverage and strengths

Data files such as high-resolution images, voice and video may require higher speed and stable network for uploading into WaGoSy and sharing. Since the majority of participants indicated the use of mobile phones, this level of mobile network accessibility was a challenge. To address this challenge, mobile telephony can be combined with the internet and community radio to provide a last mile solution for the majority of community members. World Bank Group (2016) report shows that a growing information society would reach a level where connectivity will actually be a normal business. However, connectivity alone without purpose would not help to solve pertinent problems faced by our societies. One female participant in a key informant interview on 25th March 2015 lamented about the high costs of accessing devices and mobile networks:

> ICT contributes a lot to social and national development. If possible, the Government should make all ICT devices tax free. (Interview participant, Nyakato, Ilemela)

Moderate to low network, high costs of acquiring geo-coded devices, inadequate motivation, and inadequate awareness are key roadblocks to inclusivity.

3.3.4. Educational backgrounds

Engaging with technological solutions require some skills. Educational levels indicate abilities to interact with system devices specifically geo-coding tools and WaGoSy in general. Results indicated varying levels of highest education attained by participants (Table 4).

Table 4: Summary geographical distribution of participants by education levels

Geographic Location	Highest level of education (*n*, %ge)					
	Primary education	***Secondary education***	***Post-secondary education***	***Adult education***	***None (illiterate)***	***Total***
Urban	46 50.55%	16 17.58%	28 30.77%	0 0.00%	1 1.10%	91 100.00%
Peri-urban	47 52.81%	4 4.49%	21 23.60%	2 2.25%	15 16.85%	89 100.00%
Rural	54 76.06%	9 12.68%	0 0.00%	0 0.00%	8 11.27%	71 100.00%
Total	**147** **58.57%**	**29** **11.55%**	**49** **19.52%**	**2** **0.80%**	**24** **9.56%**	251 100.00%

ns Means not significant; ***, **, * Means significant at 0.001, 0.01 and 0.05 respectively.

Majority from across geographic locations were primary school leavers (58.57%; N=147). However, again, on a cross-location basis, there were over 31% (N=78) participants who attained either secondary or post-secondary education. Since engagement as the citizen scientist, sensor or actuator is not skill-intensive at the beginning (see EU, 2013; Bonney *et al.*, 2009), these education levels could be an opportunity for further specialised training.

3.3.5. Awareness and mastery of system language

Survey through questionnaires indicated lack of awareness about the geo-coding devices, about WaGoSy and about social media. Qualitative data through focus group discussions and key informant interviews revealed a perceived difficulty in learning geo-coding and the way to integrate the whole process in WaGoSy environment.

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Although many thematic areas emerged in the course of coding and analysis of discussed issues, inadequate awareness and training appeared to be the main challenge. With regards to awareness and language, participants of FDGs held on 26th March 2015 had these to say:

> More awareness should be created on what the system is, how it works and how it helps the community (FGD participant, Igoma, Nyamagana)

> The government should put emphasis on ICT subjects at all education levels starting from the lower levels (FGD pariticipant, Nyakato, Ilemela)

The majority of FDG participants across the study sites supported their arguments. Likewise, key informant interview, as well as participant observations revealed the critical lack of understanding of languages used in both geo-coding devices and the WaGoSy.

3.3.6. Motivation to engage with geo-coding tools

Motivation to engage with citizen-based geo-tools varied across geographic areas studied. Figure 8 presents answers on motivation perceptions from 81.27% (N=204) of all participants in the study area. Cumulative of 68.7% of all participants felt that they would be motivated if given some form of financial incentives.

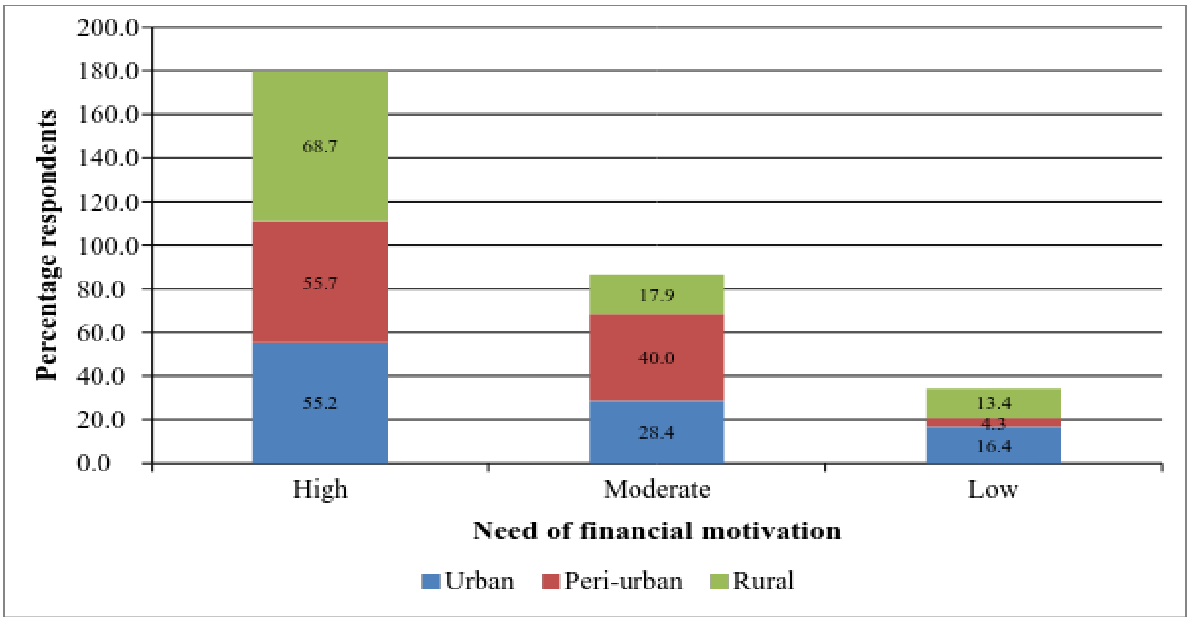

Figure 8: Perception of motivation by geographical locations

Since engagement as citizen scientists, sensors or actuator is mainly on voluntary basis, motivating the public to participate is equally important. Demand for financial incentive among the participants could be linked to their sources of income (Figure 9).

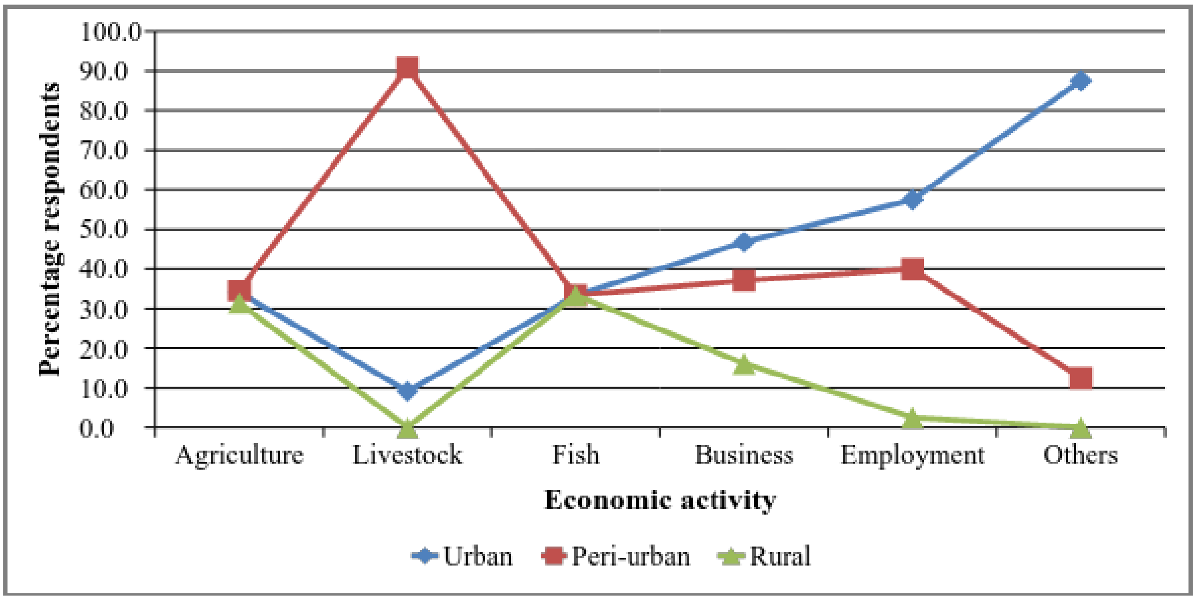

Figure 9: Participants by economic activities across their geographical areas

The majority had income generated either solely or mainly from either agriculture or livestock, which are currently facing challenges related to low productivity. Availing more options to economic welfare would be an opportunity for volunteer citizen scientists, sensors and actuators. High levels of inclusivity are achieved when every willing volunteer has the equal chance of participating as the citizen scientist, actuator or sensor regardless of the device owned. Citizen engagement through water resource focused scientific research collaboration; sensing and sharing water resources data and information, as well as direct or indirect participation in actions towards solving water resources challenges are characteristically community inclusive initiatives.

4. Conclusion

The overall system versus user view determines the point of intersection or relevance of using geo-coding to engage members of irrigation communities in urban, peri-urban and rural areas. The system avails users' opportunity of increasing crowd-sourced data while at the same time contributing to improved data quality and trust. It also avails the opportunity for contributing deliverables at the community level of irrigators and eventually contributing to the higher goal of water resource sustainability. However, there were perceived challenges amid the opportunities including the need for provision of training as part of the citizen engagement programme, enhancing extrinsic motivation and addressing policy and regulatory challenges with regards to accessibility of cost-effective hardware, software and networks required as a package for geo-coding. Some of the possible policy and regulatory interventions may include for example, safeguarding the sharing of information with interest of environmental protection; promoting access and use of hardware, software and networks through cost-related incentive packages and provide for inclusive capacity building on location-based data in water related projects. These have to be addressed in order to maximise the "dividends" of utilising citizens and technologies in solving water-related problems.

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