Global Scientific JOURNALS

GSJ: Volume 11, Issue 11 November 2023, Online: ISSN 2320-9186
www.globalscientificjournal.com

Accessibility Analysis to Improved Public Water Sources in Kigali City, Case Study of Rwampala Cell"

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ABSTRACT

Accessibility to improved water is essential to human being though various uses such drinking, washing, industries and many others for human development. Therefore, adequate accessibility is one of the aspects accounted to ensure the wellbeing of people. The current study focuses on the analysis of physical access to improved water sources in Kigali city with the case of study Rwampala cell.

The physical access to improved water sources was analyzed by computation the distance travelled to improved public water sources, and the level of coverage of improved public water sources within the study area. Data was acquired though, field observation, google earth. Field observation has been used to observe the actual location of the public water sources and distribution. Google earth and GIS base map have been used to collect coordinate points of these public water points, and accurate boundary of the study area. Spatial analyst tools available with ArcGIS were used for analysis and mapping.

The result revealed that, the available public water sources are the IPWS supplied by WASAC, unprotected spring and river Rwampala distributed in Rwampala cell. However, this research study has focused on the accessibility to improved public water sources as supplied by WASAC and accessed by majority people. Despite uneven distribution of IPWS in Rwampala cell, around 81% of the households are located within an acceptable distance (200 meter). Therefore, in measuring the current level of access to drinking water source in a community it is recommended that, researchers should use GIS analysis. In the provision of water infrastructures, the planners and decision makers should consider the use of GIS analysis to ensure the standard access and evenly distribution of drinking water source and making collaborations among local community, government and non-government organizations by taking into account the importance of drinking water to maximize the standard access to all people.

Keywords: *Water, Water source, water access and water supply.*

1. INTRODUCTION

Water is common fundamental to life and in sustaining the environment as well as enhancing the social and economic development of our wellbeing. Improved water accessed within standard distance and available for affordable price is very important to population development and human health, it is used as consumption for drinking or for utilization in different activities such cooking, recreational purpose and domestic use. Access to improved water and sanitation associated with better management of water resources plays a crucial role in developing countries where its impacts the well-being and national development plans (Mukanyandwi, et al, 2019)

However, defining and measuring the water access as an intangible concept has been applied and employed by many stakeholders in water sectors from international donor agencies, development partners, national government, civil society organization and researchers (Mwamaso, 2015). Accessibility is the key aspect considered in measuring the standard level of accessing drinking water source. The analysis on the accessibility level to improved drinking water with the integration of spatial analysis tools is still low, in determining the households access and distributing drinking water sources.

Water is the colorless and odorless substance found all over world. Water is made up of billions of molecules. Water on our planet flows as liquid in rivers, streams and oceans, is solid as ice at the north and south poles and is gas(vapor) in the atmosphere. Water is also underground and inside plants and animals). water is connected to every form of life on the earth. Adequate, reliable, clean, accessible, acceptable, and safe drinking water supply has to be available for various users (Dinka, 2018).

Accessibility of water is the way in which people can get drinking water with affordable price within standard distances. A number of basic service parameters are used to access the adequacy of domestic water supply are: quality, quantity (service level), accessibility, affordability, and continuity (Lannerstad, 2012). Globally, it is estimated that 89% of people have access to water suitable for drinking (Dinka, 2018).

World Health Organization 2019 has stated that; in 2017, 71% of the global population (5.3 billion people) used a safety managed drinking water service, 90% of the global population (6.8 billion people) used at least a basic service. A basic service is an improved drinking water source within a round trip of 30 minutes to collect water. 785 million people lack within basic drinking water service, including 18 million people who are dependent on surface water. Globally, at least two billion people use drinking water source contaminated with faeces. By 2050 half of the world's population will be living in water stressed areas.

In Rwanda, water and sanitation sector specifically, people with access to clean drinking water increased from 68% to 74.1% in 2012. People with hygienic sanitation increased from 38% in 2006 to 74.5% in 2012. According to EICV 4 survey (2014) 90 percent of the urban population are using an improved water source but only 60.5% have access to it within 200meter, which is the maximum distance considered to be acceptable for urban habitant in Rwanda. Only 39.4% of urban households have piped water within their dwellings or yard (Andre&Sarah, 2020).

In Rwanda the rural population with access to safe drinking water in 2015 was 71.9%, and urban population with access to safe drinking water in the same year were 86.6% (MININFRA, 2016). Water sources in Rwampala cell include; Rwampala river, unprotected spring from hill, rain water, and protected drinking water supplied by WASAC. The aim of this study is to know and understand level of physical accessibility to protected drinking water in Rwampala cell, so that if it is poor, measures should be proposed to address the problem prohibiting effective access to drinking water.

Adequate access to clean, safe and protected drinking water is essential concern of World Health Organization and other institutions (WHO) including United Nation Program for Development (UNPD) as the priority must be given to every human being all over the world as an important thing required in human body, personal hygiene and needed in everyday life activities (Michael, 2014). However, the concepts of population growth and urbanization have become barrier for adequate access to drinking water.

More people are living in poor communities with limited access to basic infrastructures and services especially access to potable water. Some parts of the city do not have access to public water supply, and in places that do, supply is rationed and moreover erratic and unreliable (Michael, 2014). The concept of sustainable development and the increasing pressure on water resources have led to the definition of projects and programs for the conservation of water resources (Mario and Daniela, 2017).

According to United Nations Development Program (UNPD)report, one out of six people do not have access to clean water, that is about 1.1 billion people lack access to safe drinking water and 2.6 billion people lack adequate sanitation (Dinka 2018).

The global health burden associated with this condition is staggering, with an estimated 4000- 6000 children dying each day from diseases associated with lack of access to safe drinking water, inadequate sanitation and poor hygiene. (Christine and Richard, 2006). In fact, urbanization in developing world is associated with population growth resulted in urban migration (rural-urban migration) and/ or nature growth which increase the demand of drinking water, the rapid rate at which urban areas in developing countries are being transformed by increasing populations and continued urbanization presents formidable challenges to address water supply needs of their populations (Michael, 2014).

The African continent has a high population growth rate of 2.6% but rates of access to potable water and sanitation are lowest in the world. Indeed, only 62% of its population has safe drinking water compared with 82% at the global level. However, in the rural areas, where over 60% of the African population lives, the deficit is much worse with only 34% of the population having access to drinking water as against 71% at the global level. (Ngendahayo et al, 2003).

Urban water supply in Kigali city undertake reform and revise tariff to improved operational performance and ensure financial viability of urban water services under the newly established WASAC, the update water supply masterplan for Kigali city taking into account urban growth and protected settlement patterns, promote investment in urban water supply to expand production capacity and rationalize distribution network, develop pro poor programs to serve low income households including improved management of public kiosks and social connections(Unicef, 2018).

In Rwanda, the level of accessibility to improved water in urban areas have to be in 200 m and 500m in rural areas as the standard distances established, however, in 2014 rural households within 500 m to improved water source were 47.3% and urban households within 200m to improved water source were 60.5% (MININFRA, 2016). The different studies aiming at determining the level of accessibility to improved drinking water have been conducted by different researchers, but few used of geospatial tools available with GIS as relevant tools to determine the level at which basic infrastructure, water supply infrastructures included, are servicing the population. This study seeks to examine the accessibility to improved public water sources in Rwampala cell.

2. Data and Methods

2.1. Description of the study area

Kigali city as the capital city is located at the center of Rwanda, it has three districts; Gasabo Nyarugenge and Kicukiro districts, this study conducts on the Nyarugenge district as the heart of city center of Kigali (which is towards the west of the urban area and the province), and contains most of the city's businesses it has total surface area of 134km^{2}and total population of 284561, with population density of 2100people/km^2 (NISR, 2012).

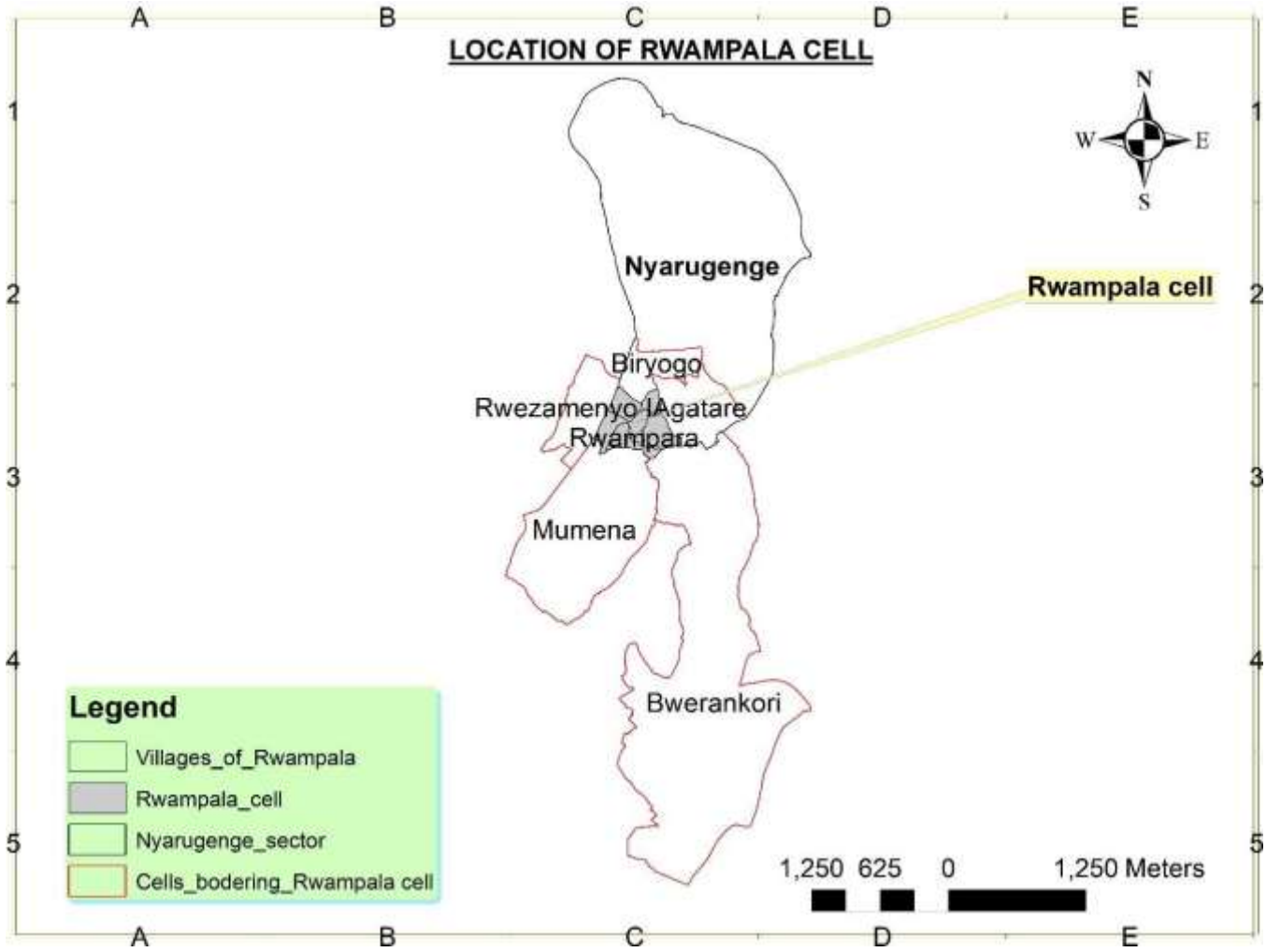
Kigali city is located on the elevation of 1555 m above sea level, this city has tropical climate, it has average annual temperature is 20.7 ^{o} C, where the highest temperature occur in August and November is the coolest month of the year, with the average annual precipitation of 991 mm, where the least amount of rainfall occurs in July, the average of this month is 5 mm and in April the precipitation reach its peak with average of 146 mm (Rwanda meteor, 2015). Kigali city has different land uses, residential, commercial, agricultures in wetlands, administrative hub, and industrial zone and so many others (Malonza et al, 2020).

Nyarugenge sector where Rwampala cell is one of the sectors of Nyarugenge district, it is located in the northeast of Nyarugenge district, this sector is bordered with 7 sectors, where Gitega, Muhima, Nyamirambo, Nyarugenge and Rwezamenyo are in Nyarugenge district, and the remaining Gikondo and Kigarama are in Kicukiro district. Muhima sector in the northern part, Gikondo and Kigarama sectors in the south-east, Gitega and Rwezamenyo sectors in west part and Nyamirambo sector in the south-west. Nyarugenge sector has the total surface area of 4.625533 square kilometer, with the number of 5558 households and the total number of population 21392 people (census 2012).

Rwampala cell is located in Nyarugenge sector, Nyarugenge district in Kigali city, it has six villages; Amahoro, Gacaca, Intwari, Rwampara, Umucyo and Umuganda. The total surface area 0.300506 square kilometer, with the total number of households 1612 and the total population of 5346people (census 2012). it is bordered with Biryogo cell at the north, Agatare cell at the eastern part, Rwezamenyo 1 cell at western part and Mumena and Bwerankori cells in the southern part.

On the socio-economic aspect, this cell is characterized by residential as land use land cover where residential is the most covering part, small retail shops where the population get their needs in easy way and travel small distance, and the remaining part is the agriculture use in the part of wetland of this cell

Figure 1: Geographical location of Rwampala cell



Source: CGIS, February 2021

2.2. Methodology

The purpose of this section introduces the research strategy and methods applied in the research and showing the steps of the research study. Different methods, techniques and tools have been used to collect data and analyze data collected related to improved public water sources.

2.2.1. Data collection

As mentioned above, both primary and secondary data in relation of accessibility to improved public water source in the study area were collected. The primary data acquisition approaches have been used to investigate the research objectives. The primary data acquisition focuses on understanding, and observing the situation and the pictures of the current situation to have the accurate rather than trying to predict.

The field observation has used to observe the current situation of the availability of sources of improved water supply in the study area, distribution of improved public water sources in Rwampala cell which to collect the coordinates location of improved public water sources by using google earth becomes simple due to the observation have been made before and then integrated into GIS for further analysis to produce suitable map

that localizing the distribution of these improved water sources within the households of Rwampala cell.

Secondary data collection refers to the way in which information are acquired from different sources. Therefore, the sources of information which has been used in this study are documents such as hard books from library of university of Rwanda, as well as e-resources such as books, journal articles, conference papers and student's theses where some information from institutions have accessed via internet like WHO, UN, UNPD, MINIFNRA, NISR, and WASAC. These documents have helped this study to understand the perspectives of other scholars on the topics related to this study including the conceptualization of accessibility, problem rerated to it, and therefore, these documents have helped us in this research to draw the contextual conclusion and recommendation so that the proposed recommendation are distinctive and suitable to the problems that limiting the adequate accessibility of drinking water in Rwampala cell.

2.2.2. Data entry and preparation

This study of accessibility to improved public water sources there are need of the dataset of households and those of public water sources. The data for households were available from CGIS and the required is the dataset of public stand posts of improved drinking water and we have working with GIS online and we add the base map and overlaid the boundary of Rwampala cell, so as to easily identify boundary of the study area with ground real world, settlement identified as an urban area and due to the field observation has conducted the location of improved public water source were recognized it were easily and able to identify them. Within GIS we have created different feature classes which represent all public water source available in this area, and then we digitized one to one, and the position coordinates that assign these water sources obtained by this method were compared to that of field observation method have conducted to ensure their accuracy.

2.3.Data analysis

After the collection both primary and secondary information, the information from desk review have been analyzed and taking the relevance information related to methods used by recent researchers to present the accessibility level of drinking water so that this study conducted in the study area has built on the facts of other scientific scholars. Moreover, the primary data collected by different tools such as Google earth software, are entered in computer, analyzed, processed, tabulated, calculated, interpreted and visualized and presented by different software like Microsoft word, Microsoft excel and ArcGIS. Therefore, the results are exported and presented in forms of tables, pie charts and maps.

GIS tools have used in this research to analyze the closeness of the collected points indicating the location of improved public water sources related to the households of Rwampala. Directional distribution tool used in the analysis of types and distribution of water supply in this area, indicating the villages which have standard access than others as well as the direction of these stand posts. Multiple ring buffer tool used to indicate spatial accessibility by distance, it determines the level of households accessing to each of the public kiosks within 200 m and 500m. Thiessen polygon tool has been used to allocate the space to the nearest public stand post and indicate the area in which the households should get drinking water from public stand posts, in which every location is nearer to this public standpipe than to the remaining others.

To determine the accessibility of households to the public standpipes of drinking water, we have employed near analysis method, it produces a table that contain distances travelled by the household to access to the near water source. Therefore, we also produce maps that show the location of the study area. Microsoft word and excel used to produce tables, interpretation of the results.

3. RESULT AND DISCUSSION

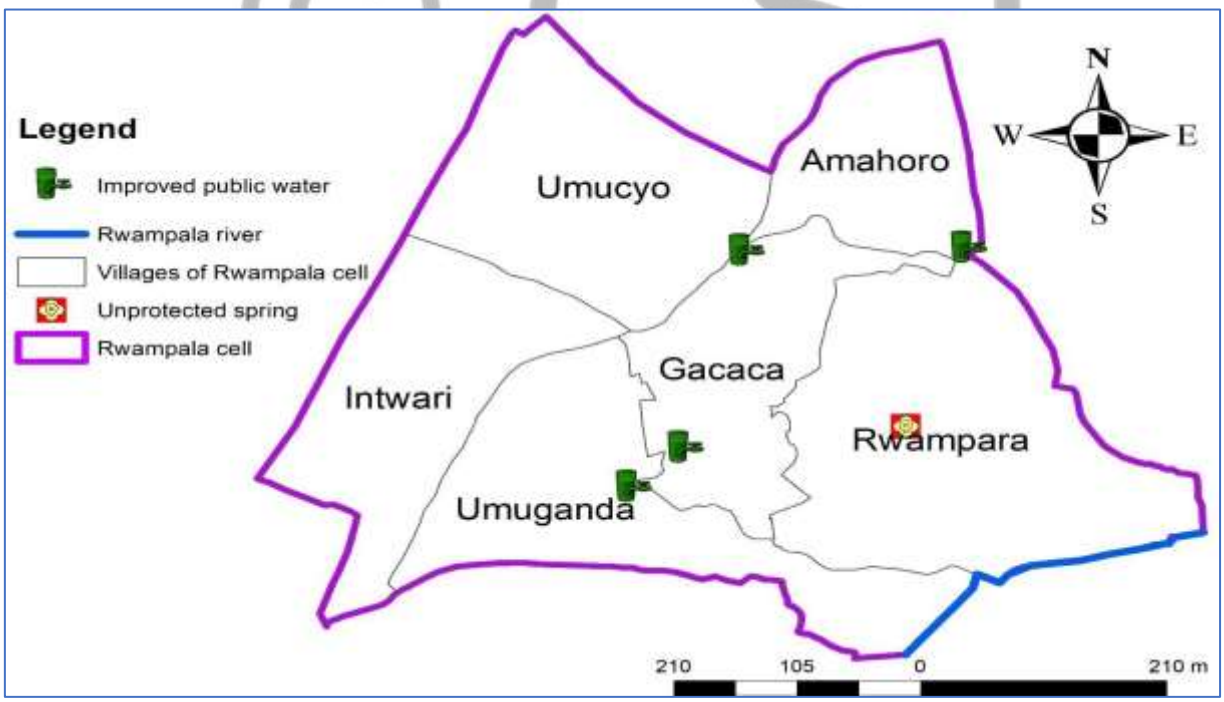
This section presents the result of analysis of data collected related to all available public water sources including improved public water sources in Rwampala cell. The analysis focused on distribution of improved public water sources and the level at which they are spatial accessed by the people of this area.

3.1.Distribution of public water supply accessed in Rwampala cell

The population of Rwampala cell are serviced by water supply system operated by Water and Sanitation Corporation (WASAC) and other local water sources where everyone can access them with their own sake of purpose, like building, washing car, and so many others, among these water sources include the spring located in Rwampala village and river Rwampala, etc. the water supply system under WASAC consists of the piped water serving the population within dwellings (household connections) and water kiosks. However, this study focuses only the analysis of improved public water source (water kiosks).

Improved water provided by WASAC some are directed to connected to the dueling for private use while others households of this cell access the water from improved public water sources distributed in this area and beyond the boundary of this cell that are available in near distance of 200 meter as acceptable standard distance in urban areas. The figure 5 illustrates the availability and distribution of public water sources in Rwampala cell.

Figure 5: Distribution of all public water sources in Rwampala cell



Source: Authors, February, 2021

The google earth image has used to illustrate the location of public water sources used by Rwampala households with marking precisely where some these water sources are located either within the boundary of the study area or beyond, where Rwampala cell has only four water kiosk, one unprotected spring and river and the remaining four water kiosk locate in the neighboring cells of Rwampala cell in the distance of 200 meter from Rwampala boundary.

Figure 6: Location of public water sources used in Rwampala cell on google earth

Source: Authors, March 2021

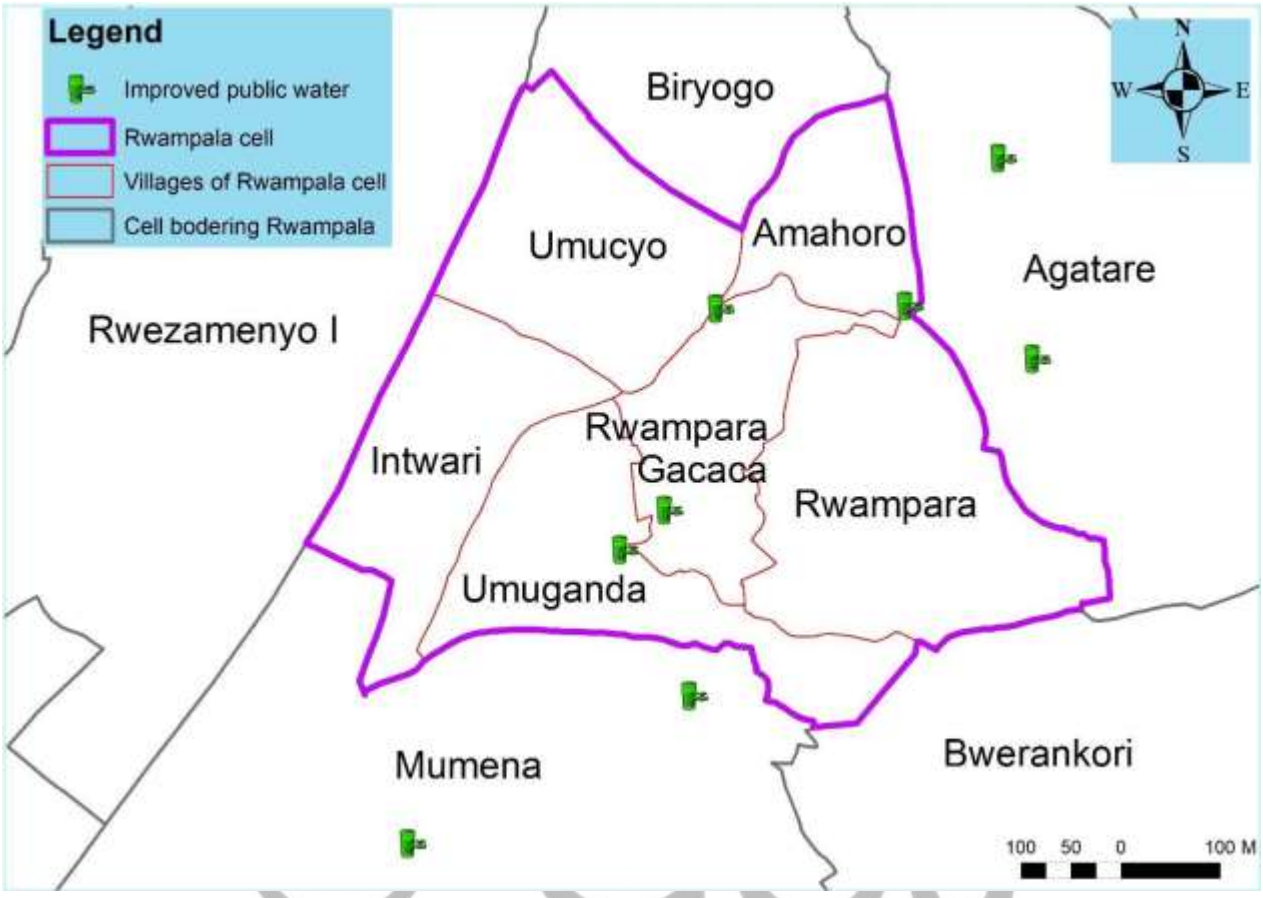
3.2. Distribution of improved public water sources infrastructures in Rwampala cell

The spatial analysis has shown that there are only 4 public improved waters provided by WASAC distributed in Rwampala cell but near the boundary of this cell there are other 4 public standpipes that are close and accessed by the households near them. In fact, for those kiosks found in the boundary of Rwampala cell, two of these standpipes are located in Gacaca village, 1 located in Umuganda village close to one of Gacaca village and the fourth is located in Amahoro village.

United Nation General Assembly 2010, explicitly recognized the human right to water and sanitation and acknowledged that clean drinking water and sanitation are essential to the realization of all human rights. In that case, the accessibility to improved public water sources do not limit to any of the administrative boundary, therefore, some of the households of this study

area get drinking water from the public water that are close and easily accessible to them, found in the neighboring cells. The figure 7 illustrate the distribution of these improved public water sources found of Rwampala cell and those of neighboring cells and their location as well.

Figure 7: IPWS accessed by households living in Rwampala

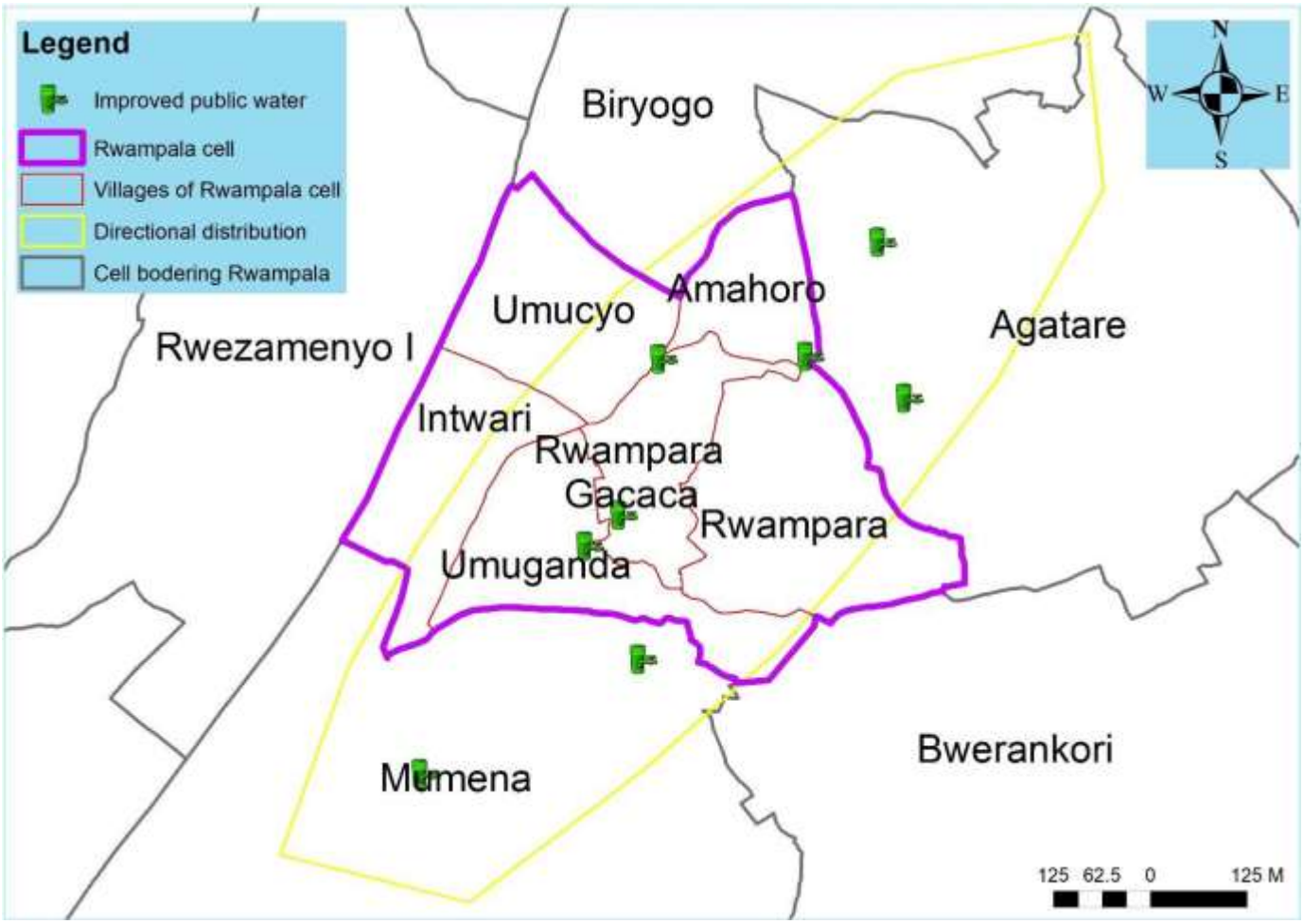


Source: Authors, March, 2021

3.3. Direction distribution of improved public water sources (IPWS)

The distribution of public standpipes has to be reliable and equally accessed in standard distance, therefore, improved public water sources accessed by the Rwampala households are distributed from southwest to northeast of this cell and are close to each other than being distributed with respect to the spatial location of households. Households from Umucyo, Intwari and Rwampara villages do not have their own standpipes the based on the boundary of this cell it is not evenly distributed with public improved water, but access from other villages of Rwampala cells and from neighboring cells.

Figure 8: Directional distribution improved public water sources



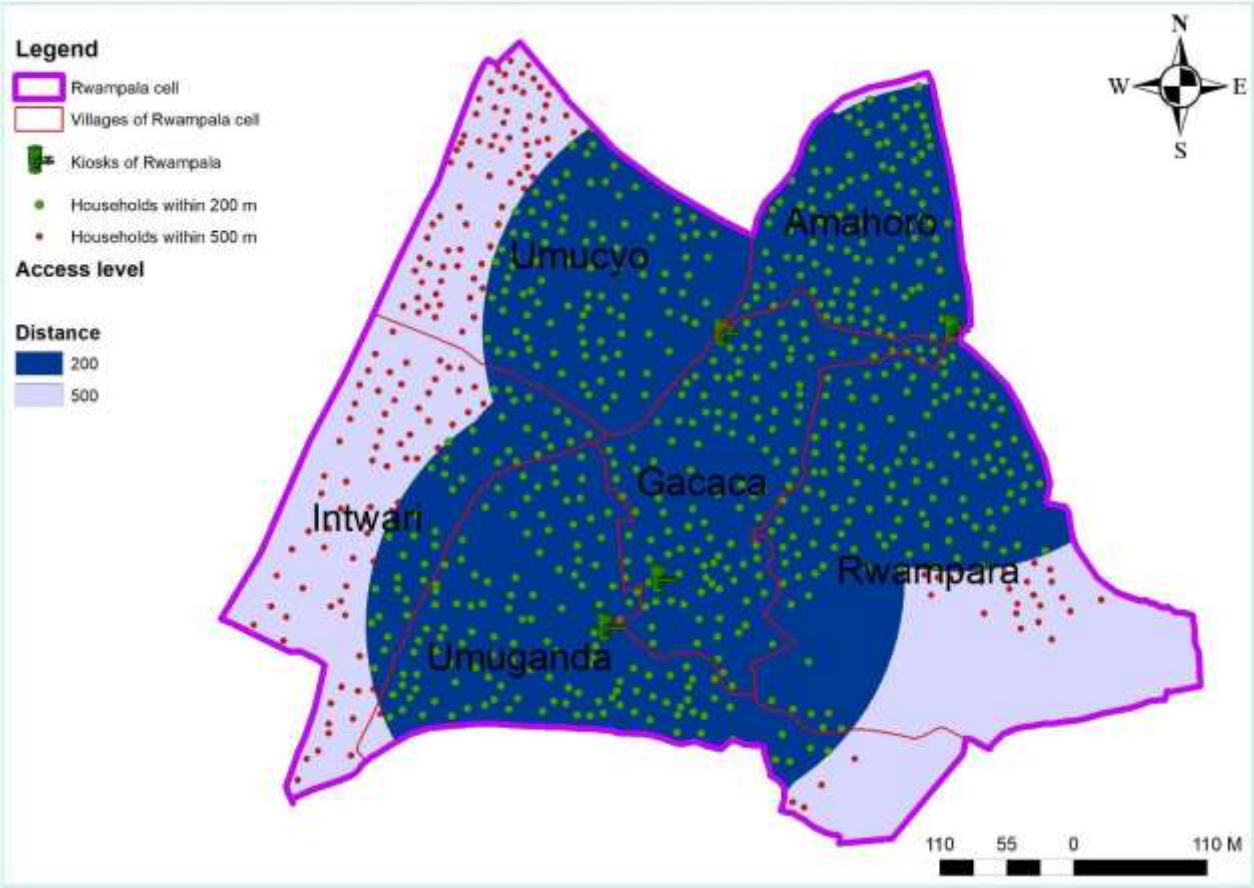
Source: Authors, March 2021

3.4. Level of coverage of improved public water sources in Rwampala

3.4.1. Proximity to improved public water sources

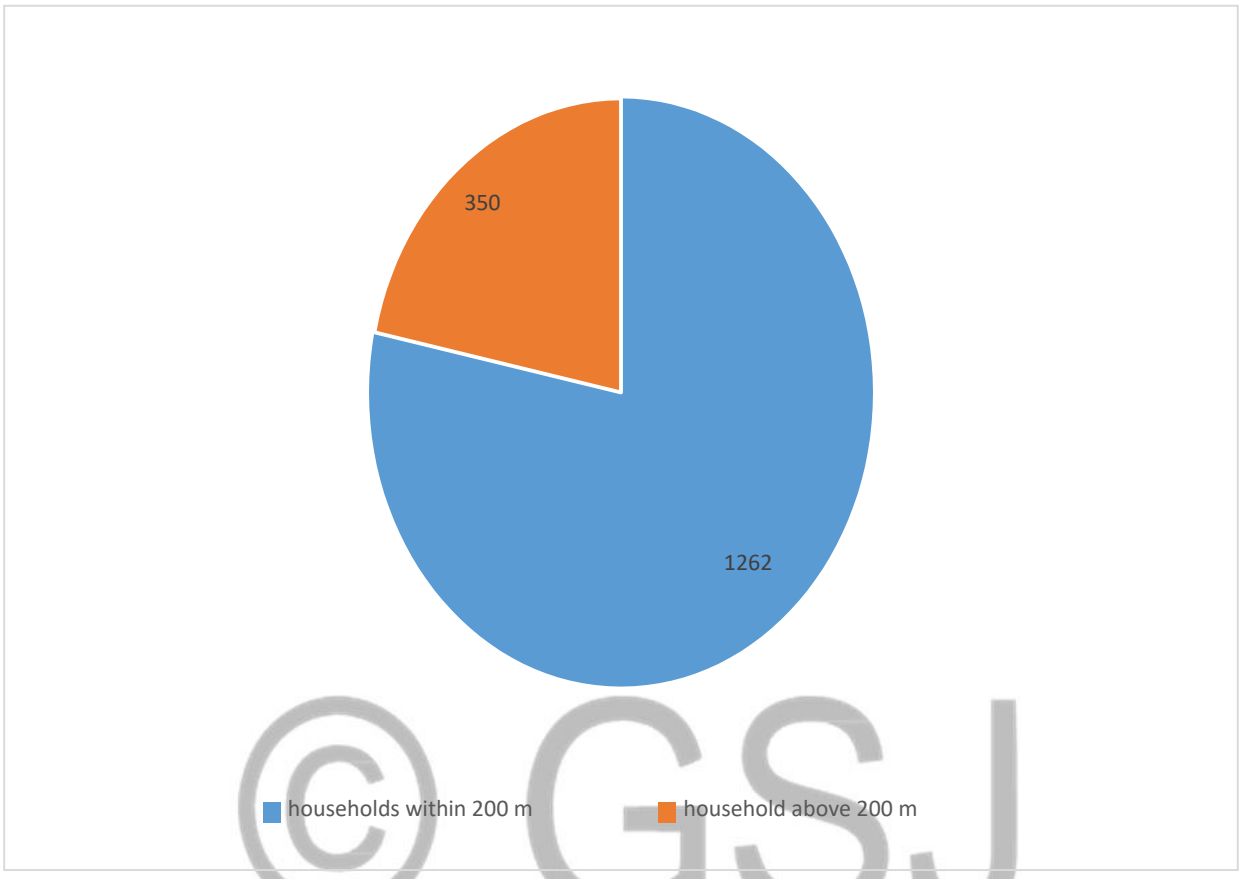
Proximity to the improved public water sources is essential aspect in accessing the accessibility level of the households as they provide the distance from improved public water source to households. ArcGIS multiple ring buffer tool was used to find the proximity to the improved water sources, the figure 11 indicates the different level of access in which these households that lies within the buffer of 200 meter have good access, and buffer of 500 meter have poor access of access to IPWS Rwampala

Figure 10: Multiple ring buffer to only IPWS of Rwampala



Source: Authors, March 2021

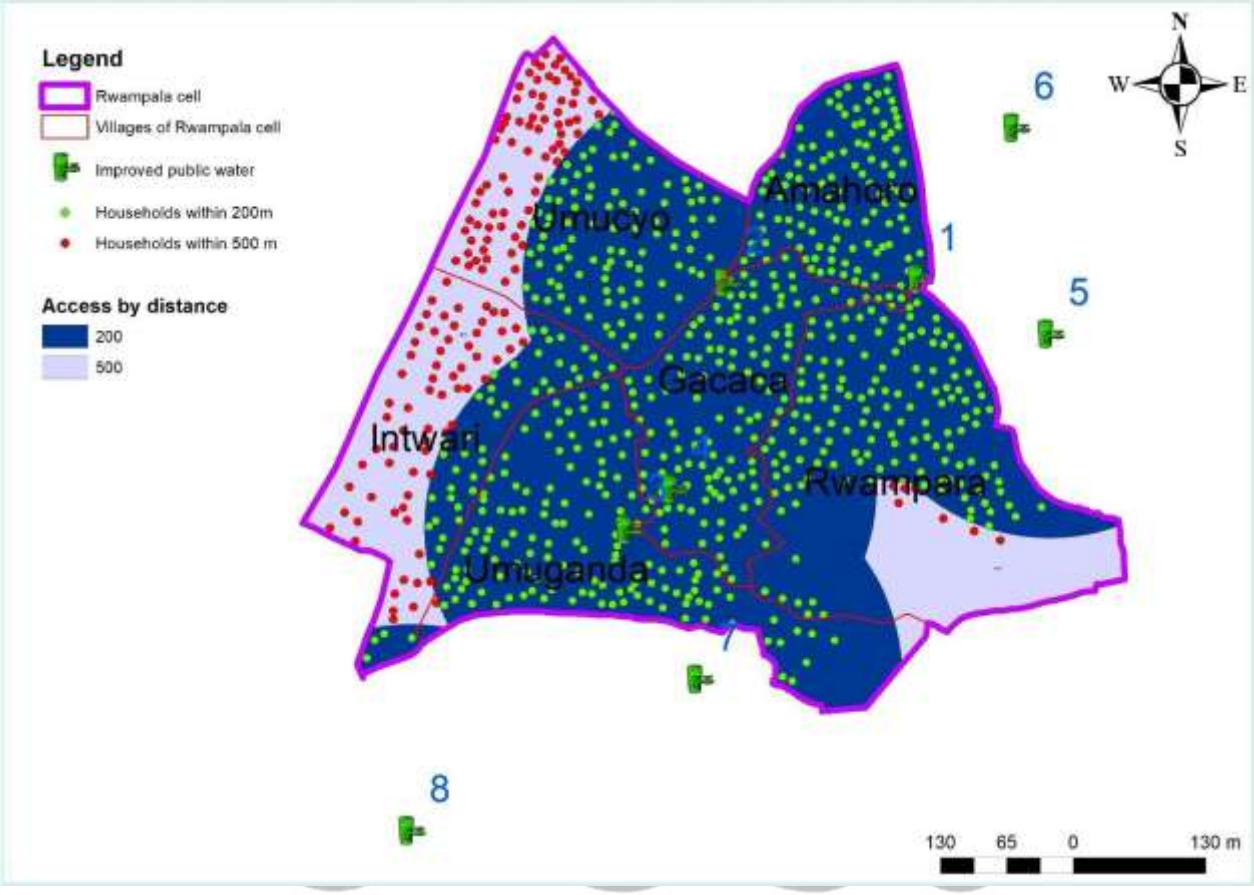
Figure 11: Pie chat of accessibility level to IPWS of Rwampala



Source: Author, march 2021

In Rwanda there, there is no restriction related to administative boundary for accessing drinking water source, in fact, people from Rwampala get drinking water from the near IPWS even some are found out of boundary of their cell. This spatial analysis results examined the households which will lied in distance 200 and 500 meter from improved public water sources with respect to the total number of households, from the proximity map, it is seen that the majority households of Rwampala cell appear in 200 meter and illustrates that this cell is well serviced because the large number of households have standard access.

Figure 12: Multiple ring buffer to all IPWS including those of 200meter from the boundary of Rwampala cell



Source: Authors, March 2021

The table 6 illustrates the results of the level of accessibility of households improved public water sources of Rwampala cell and with addition of others located beyond the boundary but in 200 meters from the households of the study area

IPWS	IPWS accessed by Rwampala households	
Access level (meter)	<200	200-500
Number of households	1312	300
Percentage(%)	81.39%	18.61%

Source: Authors, March 2021

3.4.2. Closeness of households to improved public water sources (IPWS)

The accessibility of households to improved public water sources in urban areas has to be 200 meters based on ministry of infrastructure. In general, the distribution of the IPWS in Rwampala cell make the minimum distance travelled by the household to access to the near water source as facility to be 1.12 meter while the maximum distance travelled by the household to reach to its near water source is 292.35 meter, this is evidenced by the near analysis tool which indicates the average distance travelled by a household to access the near IPWS is approximately to132 meter. The table 7 illustrates the number of households accessing to each of its near IPWS and the average distance travelled by these households to access the near IPWS.

Table 7: The number of households accessing to each of the near IPWS

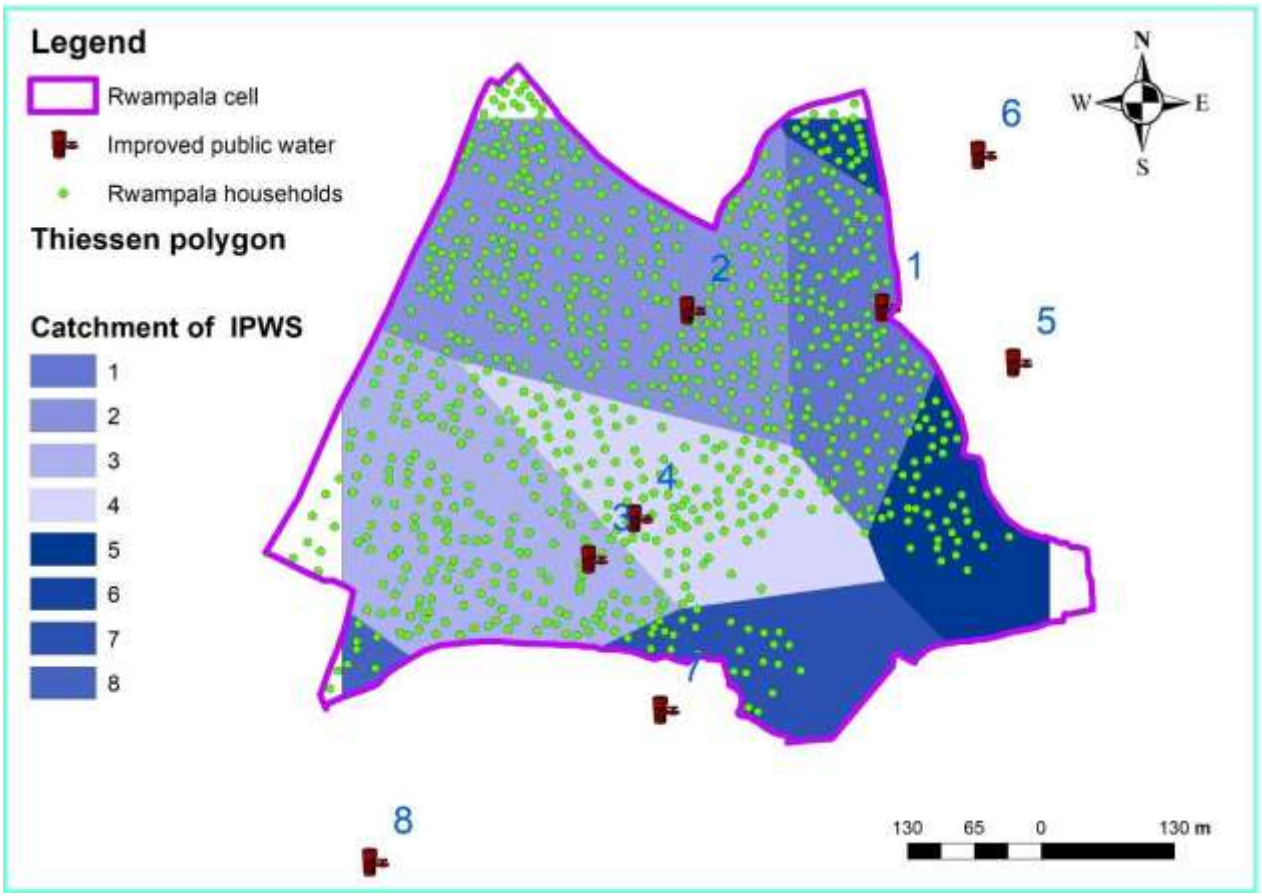
IPWS	Number of households	Percentage (%)	Mean distance(meter)
1	252	15.63	99.88
2	564	35	148.02
3	368	22.83	149.93
4	228	14.14	92.63
5	82	5.09	156.24
6	46	2.85	142.5
7	56	3.47	93.79
8	16	1	200.47

Source: Authors, March 2021

3.4.3. Coverage area of households with respect to improved public water sources(IPWS)

With the use of thiessen polygon as a tool for analysis, it is used to divide the area covered by the input points features into thiessen or proximal zones. These zones represent full areas where any location within the zone is closer to its associated input point than to any other input point. Thiessen polygon analysis has therefore used in this study to indicate and trace the polygon across the IPWS and integrate the number of households that are able to access it in near distance than any other IPWS else around it. The figure 13 shows that IPWS 2 is more spatial accessed by many households than any other, and the IPWS 8 is accessed by small number of households.

Figure 13: Thiessen polygon



Source: Authors, March 2021

The clear accessibility of households to the IPWS indicated by each polygon that contain these households with its align IPWS, its indicate where the households should get the water, the thiessen polygon indicate the area in which the included households should access drinking water source than any other else around. From the table 8 the IPWS 2 holds many households which are able to access it than other IPWS around.

Table 8: Households covered by thiessen polygon

POLYGONS	Number of households Served by thiessen polygon	Percentage%
IPWS 1	248	15.38
IPWS 2	536	33.25
IPWS 3	350	21.71
IPWS 4	232	14.39
IPWS 5	84	5.21
IPWS 6	38	2.36
IPWS 7	56	3.47
IPWS 8	12	0.74
Total	1556	96.52

Source: Authors, March 2021

From the table 8, the total number of households of Rwampala cell are 1612 where the households covered by Thiessen polygons are 1556, and therefore, the remaining households which are not covered by Thiessen polygon are 56.

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

The aim of this research study is to analyze the spatial accessibility to improved public water sources in Kigali city, the case study of Rwampala cell. In fact, the result to improved public water source with the use of spatial analysis tools indicated that they are 8 IPWS that serve drinking in Rwampala cell but not well distributed in this study area. The availability of water sources used in Rwampala cell illustrated that they are 4 IPWS available within the boundary of Rwampala cell, and 4 IPWS located out of the boundary of the study area and/but within standard distance of access (200 meter) from the households of Rwampala.
In addition, the level of spatial accessibility of IPWS in relation to the household distribution are 81% households have standard access and 19% households do not have adequate accessibility.
The result indicated by the thiessen polygon from the figure 14 has illustrated that the IPWS 3 located Gacaca village serves majority of the households of 33.25% compared with others and the IPWS 8 is the least in serving drinking water to the households with 0.74 % of households served, from near analysis, the average distance travelled the households to near IPWS is 132 meter where the minimum distance travelled by the household to near IPWS is 1.12meter and maximum distance travelled is 292.35 meter.

4.2. Recommendation

The improved drinking water is always necessary and needed in human body and used in every daily activity, and it should be available all the time in sufficient quality and quantity and accessible in standard distance. Therefore, to achieve this sustainability of water in community there is need of effective partnership among all local community, local authority level, national level and other related institutions for sustainable development to take into consideration the drinking water as priority to human health.

In the provision of water infrastructures, the planners and decision makers should consider the use of GIS analysis to ensure the standard access and evenly distribution of drinking water source to all people. when the integration of GIS tools for analysis should allocate the suitable location of new improved water source to be established in relation to both distribution households and street network connecting to the households. GIS analysis would also integrate the all impedances to access these improved water sources. For instance, in the distribution of public standpipes have to consider all people access them in standard distance of 200 meters in urban areas and 500 meters in rural areas as established. The government of Rwanda has to increase the budget invested in water provision by increasing the ability of water treatment plant to produce adequate quantity and quality to all Rwandan.

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