

The Role of Geographical Information System (GIS) in Analysis of Public Health Accessibility in Rwanda. Case Study: Nyagatare District.

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Abstract.

Access to public health facilities is an important component of an overall health system and has direct impact on the burden of diseases that affects many countries in developing countries. With the help of ARCGIS 10.6, we identified different factors in Nyagatare district that prevent the population from accessing public health facilities such as the availability and geographical location of health centers. This analysis based on the literature review to understand what other authors wrote about the concept of health facilities. Spatial pattern of health distribution was examined using average nearest neighbor and near analysis in ArcGIS 10.6 was used to determine the distance from population to health center within Nyagatare district. Travel time per patient was calculated using ArcGIS software based on the mode of transport such as driving and walking. The result shows that the most populated areas such as urban areas

in Nyagatare have more access to public health facilities than the rural areas. This analysis can assist decision makers in Nyagatare district in planning for public health services.

I. INTRODUCTION

Access to health public health facilities is an important component of an overall health system and has direct impact on the burden of diseases that affects many countries in developing world (Black et al., 2004). Accessibility to health care is concerned with the ability of a population to obtain a specified set of health care services (Oliver & Mossialos, 2005). Geographical accessibility often referred to as spatial or physical accessibility is concerned with complex relationship between the spatial separation of population and supply of health care and thus has a strong underlying geographical component (Black et al., 2004), although the

level of public health of population may be affected negatively by the distance to health care services (Guagliardo, 2004). Geographical information system (GIS) is useful in measuring physical accessibility of public health care as it contains core tools for such analysis including buffer, average nearest neighbor and network analysis tools. According to Sourman 2016, availability, acceptability and affordability and geography have been identified as the major factors preventing population from accessing public health care. With the help of ARCGIS 10.6, we identified different factors in Nyagatare district that prevents population from accessing public health facilities such as availability, geographical location of health centers and poor road maintenance. The general objective of this report is to analyze the physical accessibility of health care in Nyagatare district by identifying the distance between patients to health center and the time taken to access the health center using ARCGIS analysis tools.

II. MATERIAL AND METHODS

This analysis based on literature review to deeply analyze what other authors wrote about the concepts of health facilities. The literature review was used to acquire more information on the physical accessibility of

health facilities in Nyagatare district. ArcGIS software and its analysis tools were used to analyze the number of health facilities in the district, the distance between household to the nearest health facilities was calculated using near analysis tools and the time taken by patients to access the medical care. The graphs were performed using ArcGIS software through its graphic wizard and choosing the vertical as the type of graph and choosing the layer and table containing data of near distance in the attribute table of Nyagatare health center. The analysis of high concentration population and lower concentration population that need to be served were identified using kernel density analysis tool in ArcGIS, the spatial pattern of health distribution was examined using average nearest neighbor.

Study area

Nyagatare district is the largest and second most populated district in Rwanda. It is located in the Eastern province. It is one of the six secondary cities. Nyagatare has the population of 466,944 (National population census 2012). The total area is 1,741 Km² where 1,738 Km² is covered by land and 3 Km² is covered by water. Nyagatare district has 15 health centers and one hospital that serve the entire population. The district has

higher temperature compared to other parts of the country as it receives lower precipitation. The district is divided into 14 sectors which comprise 106 cells and 360 villages. The

district borders with Uganda in the North, Tanzania in the East, Gatsibo district in the South and Gicumbi district of the Northern province in the West.

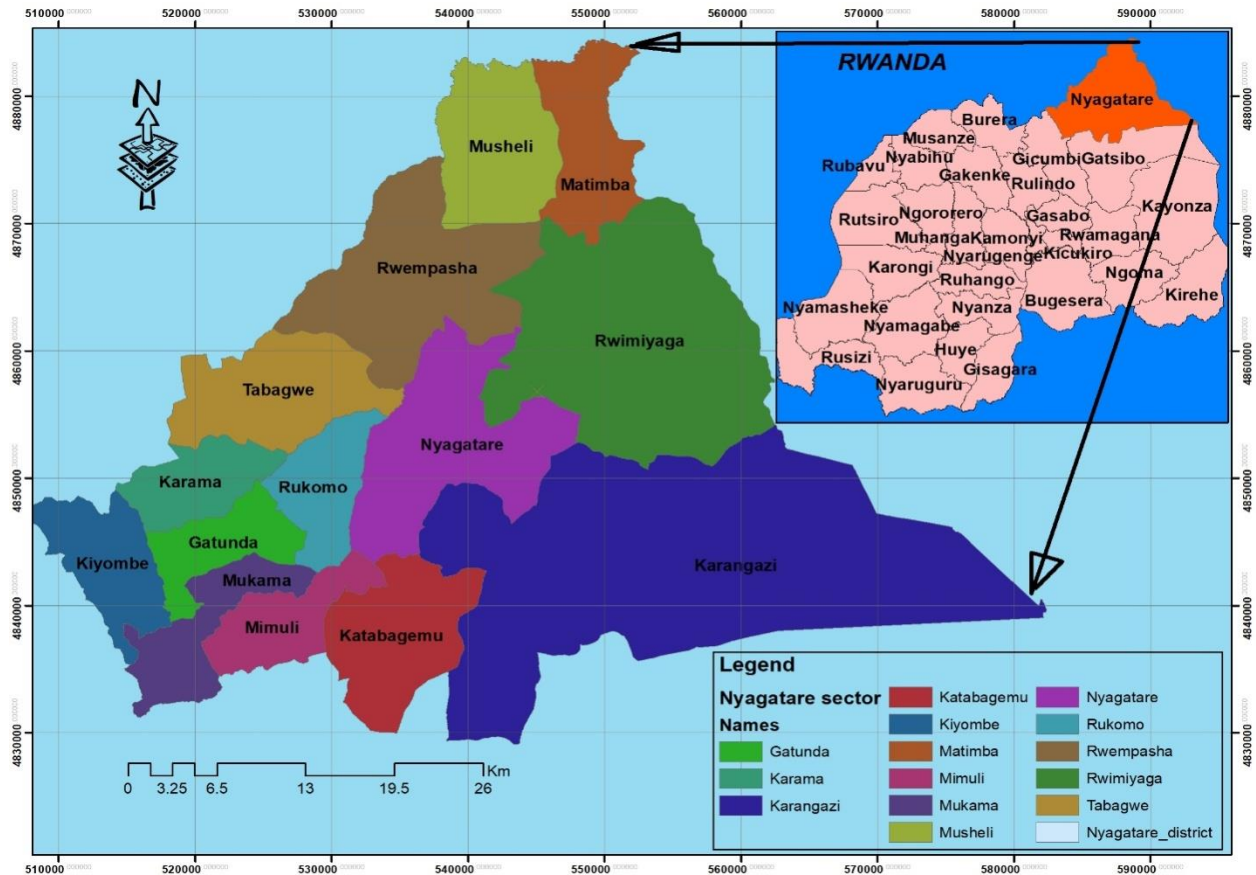


Figure1. Administrative boundaries and sectors of Nyagatare district

Mean center, directional distribution and standard distance

The mean center tool was used to determine the geographical center of public health facilities across the district. Directional distribution statistical tool were used to

determine the spatial characteristic and the direction public health facilities in Nyagatare district. Measuring the degree to which public health facilities are concentrated around the mean center was performed using standard distance spatial statistic tool.

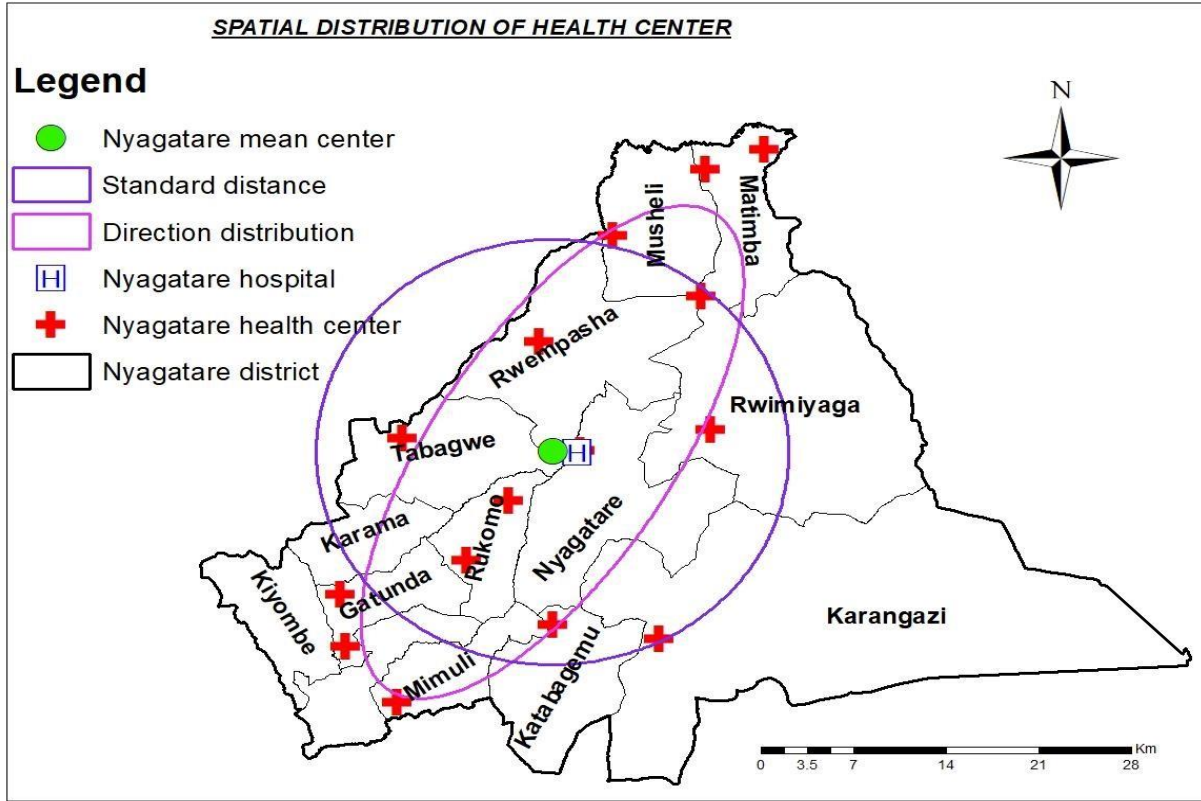


Figure 2. Spatial distribution of public health center.

Average nearest neighbor and Euclidean distance

The average nearest neighbor was performed using ArcGIS 10.6 to measure the distance between each spatial distribution of health center and all the distance was average. If the average distance of the observed distribution is less than the expected distribution, the spatial pattern being analyzed is considered as cluster. In this case, the average nearest neighbor is less than one. However, the average distance is greater than the expected distribution the spatial pattern is dispersed and the value of average nearest ratio is

greater than one. Euclidean distance tool was calculated using ArcGIS 10.4 to measure the straight line distance between the household to the closest health facility.

Near analysis tool.

Near analysis in ArcGIS 10.6 was used to determine the distance from population to health center within Nyagatare district. This also shows the closest household to the available health center in which they can have access medical services within determined Euclidean distance between the patient to public health facilities. By using

near analysis tool, all calculation was expressed in Kilometers

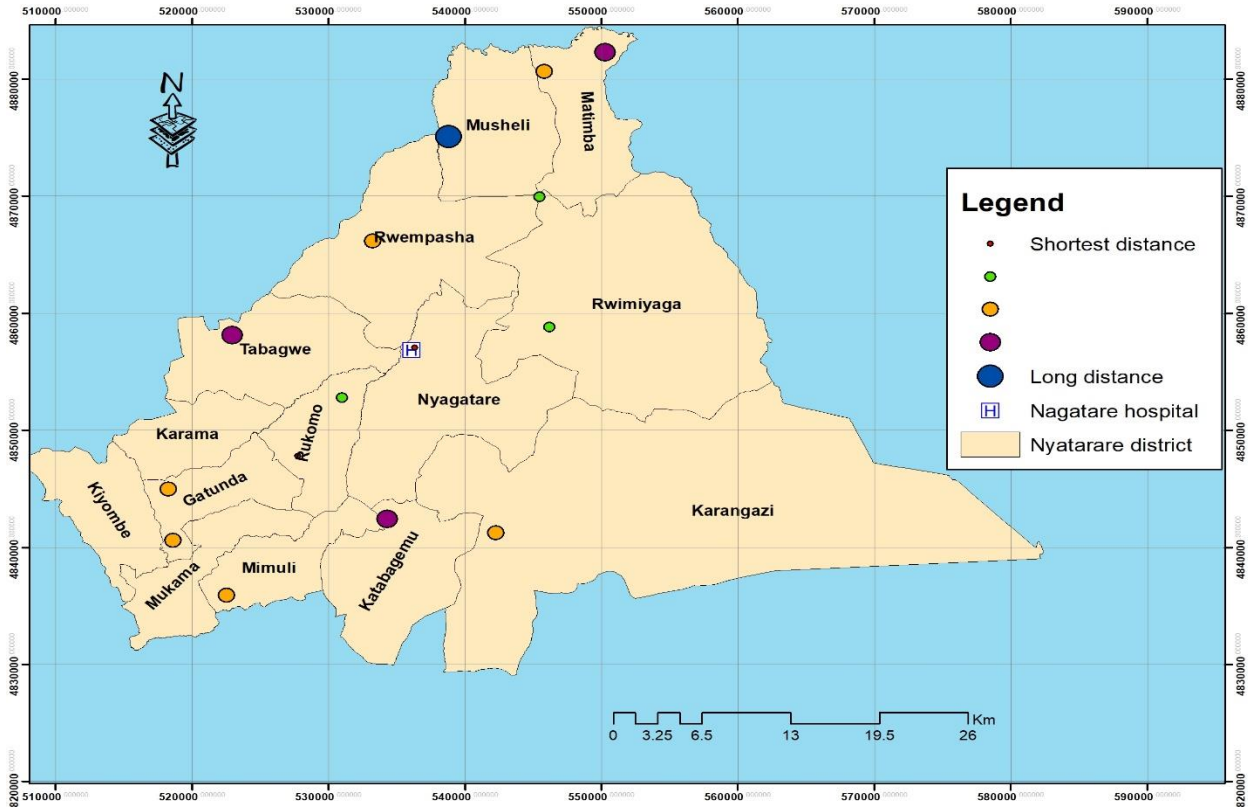


Figure3 Distance from patient to closest public health facility.

III. RESULTS AND DISCUSSION

The results and discussions are well represented in the form of images and maps, graphs and statistical tables which include the maps showing the accessibility of health facilities in Nyagatare district, time and distance taken by the patient to have access to the medical care, the spatial distribution of

health facilities. The maps will show how people are connected to the public health centers using network analysis tool.

The spatial pattern of public health distribution in Nyagatare district was determined using the average nearest neighbor in ArcGIS 10.6. The results revealed that spatial distribution of health

facilities in this district are dispersed. Due to the z-score observed in the graph below, it shows that there is less than 1 % likelihood that dispersed pattern could be the results of random chance. The analysis shows that public health facilities are dispersed from south west to north east and the big number of people living in the middle south east has

no access to health facilities. Thus, the patient has to move a long distance to reach the nearest medical center to get medical care and this makes it very expensive. Consequently, some women die when they are going to deliver because of the long distance.

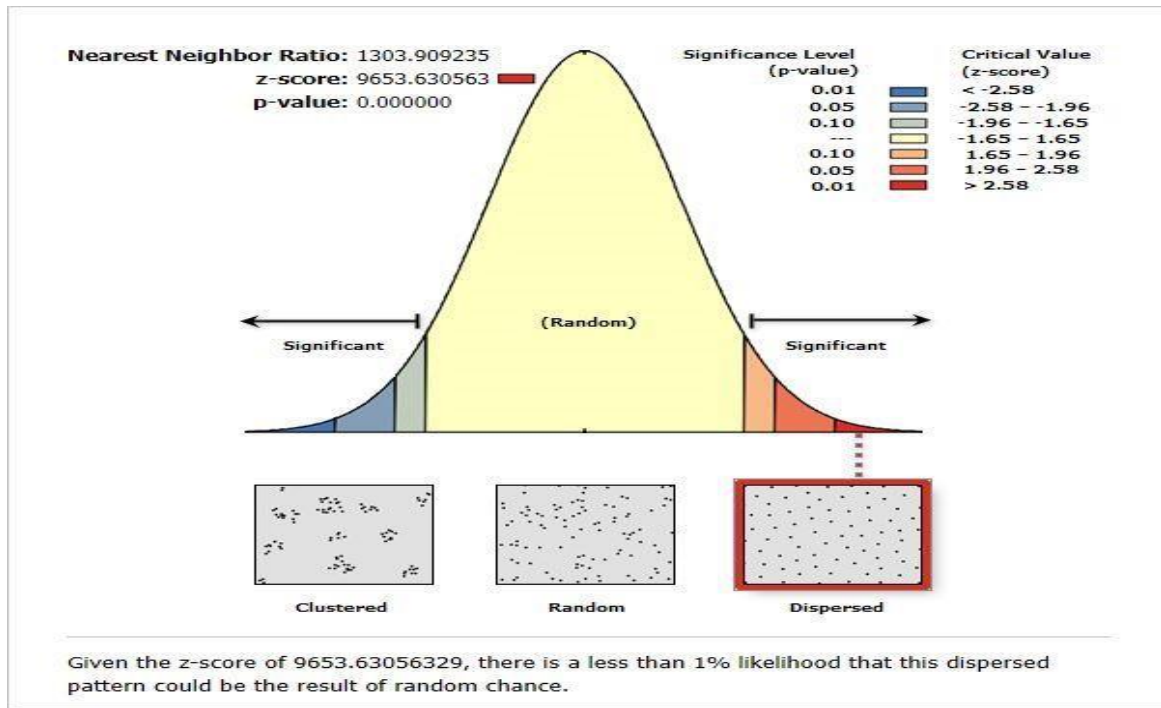


Figure4. Report of average nearest neighbor

The results from the calculation of mean center, directional distribution and standard distance performed in ArcGIS 10.6 (**Figure2**) reveals that the directional distribution of public health center extends from the North east to the South west of the district and the

reason is that high number of population are concentrated in the North east to the South west due to the topography, land cover and the planned land use in sector like Karangazi and Rwimiyaga, which are mainly occupied by wetland and Akagera National Park and

have less population, although few people live in the middle parts of the South east of Nyagatare district but they do not have any access to public health facilities. With the analysis using ArcGIS, mean center of all health facilities was observed (**Figure2**) the analysis helps to identify the regions in which the District hospital can be built so that the entire population can be well served within the same distance.

Provider to population ratio was calculated using ArcGIS software, referring to the overviews of health system in Rwanda that includes an average coverage of 200,000 people per district within one hospital per district and 20,000 people per health center, provider to population ratio was calculated basing on the number of people that a health center can receive multiply by the number of health center and the number of hospitals respectively and then divide by the total number of population living in Nyagatare district. With this calculation, we observed that the provider to population ratio was 1.17599 for health center since each health center is responsible to serve 20,000 people with the total number of 255104 of the district. Provider to population ratio to the hospital was 0.7839 since the hospital is responsible to serve 200,000 and the total

population was the same as the one that used in calculation for health center.

Near analysis tool was performed using ArcGIS 10.6 to determine the distance from the population to the closest public health facility (**Figure3**). The results revealed that some of public health centers are at a shorter distance and closer to the population as they have more access to health facilities. Such health facilities were found in sectors like Nyagatare, Rukomo, Rwimiyaga and at the boundary crossing Matimba, Rwimiyaga and Rwempasha (**Figure3**)., However other health facilities are not in close proximity and have less number of people to serve. Such facilities were found in sectors like Matimba, Musheli, Tabagwe and Katabagemu. The graph showing the distance to the closest facilities was performed using ArcGIS software through its graphic wizard and choosing the vertical as the type of graph and choosing the layer and table containing data of near distance in the attribute table of Nyagatare health center. The analysis reveals that Nyagatare health center receives more patients due to the fact that it is located near Nyagatare hospital and it is in the city of Nyagatare district. It means that the more populated areas in Nyagatare city, the more accessibility to health facility. The distance

from population to the closest public health facility was analyzed using near analysis tool and it was expressed in meters.

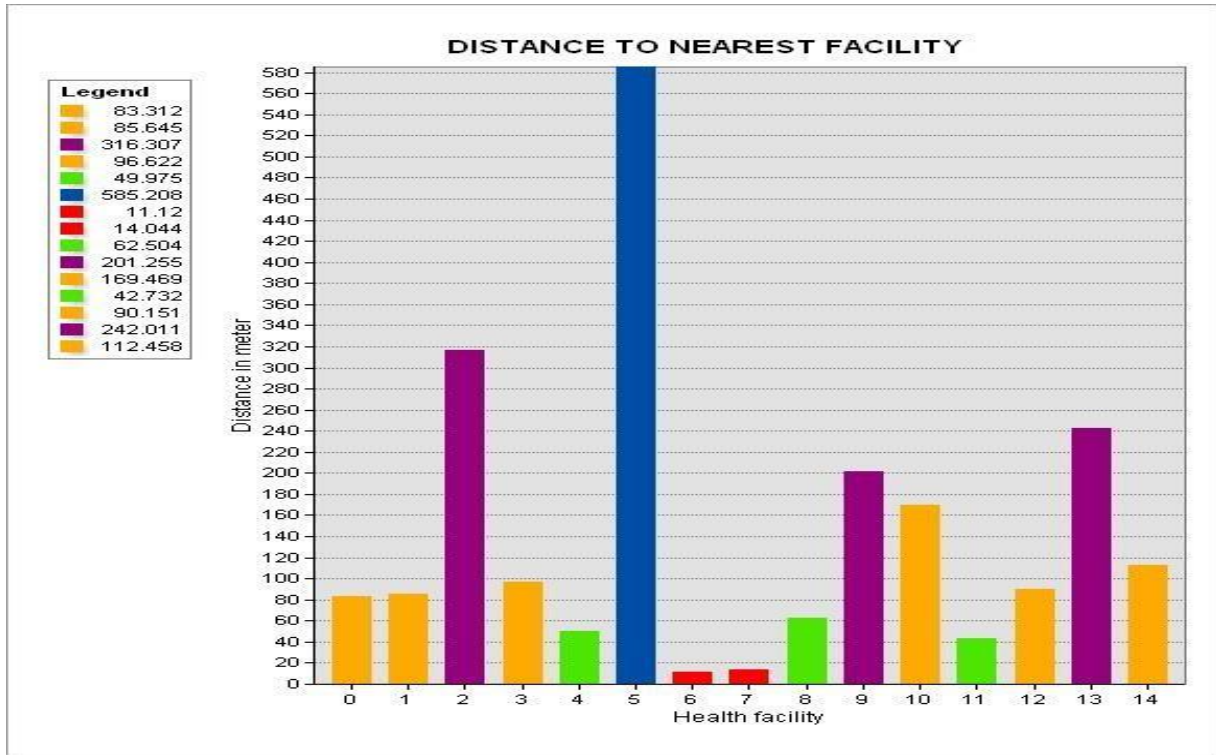


Figure5. Graph showing the distance to the nearest public facility in Nyagatare district

Kernel density tool was also performed using ArcGIS 10.6 to determine the population density in Nyagatare district. The output shows the areas which are more or less densely populated. By overlaying healthcare facility data, we visualized areas with high or low density either with some healthcare facilities or without any healthcare facilities.

and north east parts of Nyagatare are densely populated but all people are not served by healthcare facilities, which results to less accessibility as there is a big number of people who are concentrated in areas where there are not any healthcare facilities. But this becomes an issue when those people live far away from the existing facility.

Figure 6 shows that the central south west

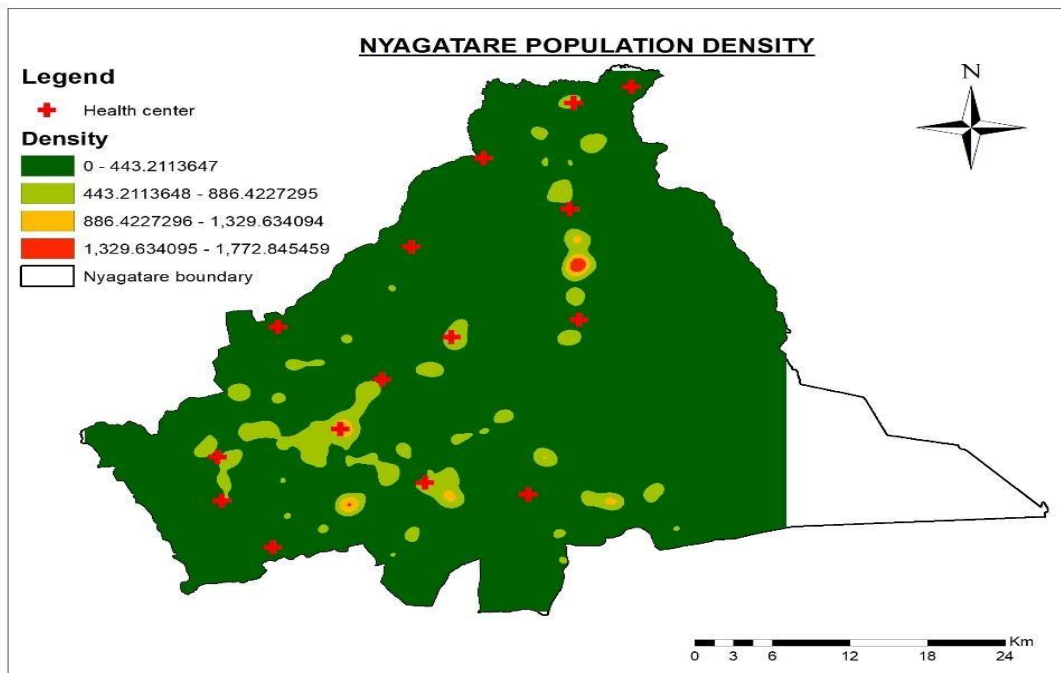


Figure 6. Areas with high concentration of population in Nyagatare district

Multiple ring buffer tool was also performed using ArcGIS 10.6 to determine straight line distance or allowed minimum distance. The multiple ring buffer was performed to determine the distance in which services of health facilities are provided according to the location of households. The result showed that the high number of people

face inaccessibility to healthcare facilities as the distance increases mostly for people who live in eastern and southern parts of Nyagatare district. This is a difficult issue to poorer people who fail to travel long distance in order to have access to healthcare facility and this results in health inequality.

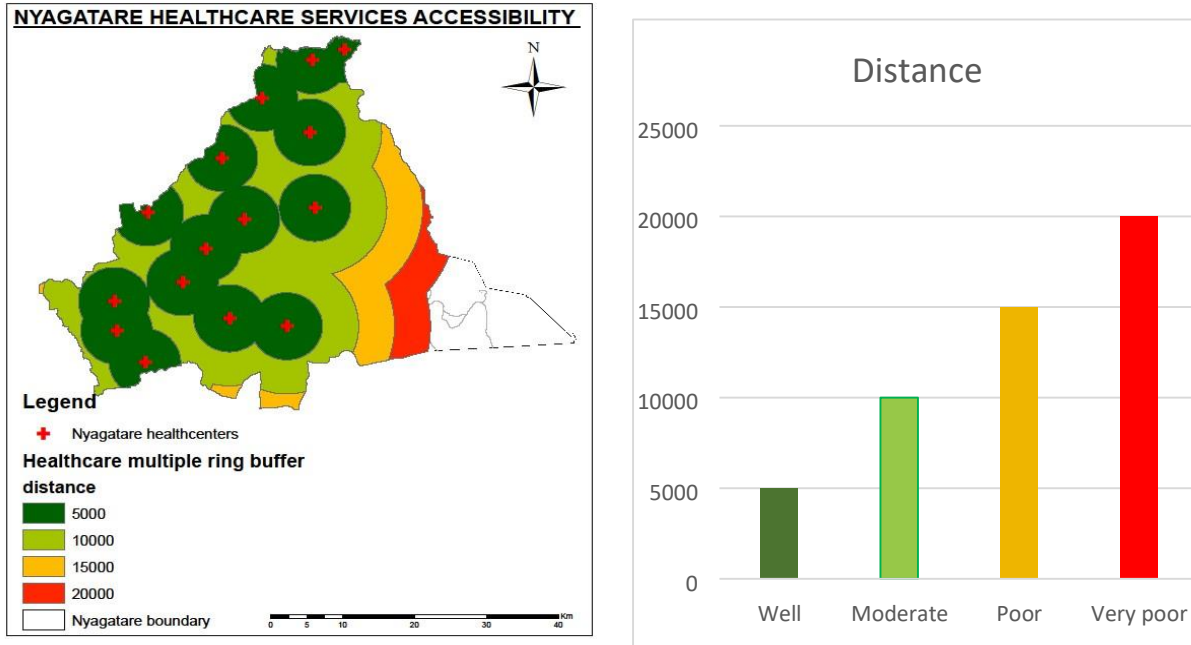


Figure 7: Services accessibility of Nyagatare healthcare facilities

Network analysis tool and Euclidean distance

The network analysis was performed using ArcGIS 10.6 to determine how roads are connected to each other. The result was used to determine the standard travel distance based on allowed 5 kilometers of walking (**Figure 8**), which shows that many people travel long distance to have access to

healthcare facilities due to impendences. As it can be observed, few blue lines show allowed travel distance of 5 kilometers from house location towards healthcare facilities. The Euclidean distance was also calculated to determine the shortest distance along the straight line between house locations and the nearest public healthcare facilities (**Figure 9**)

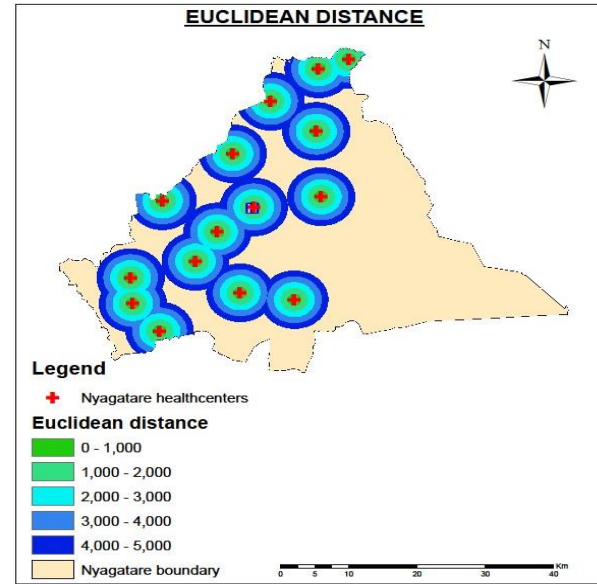
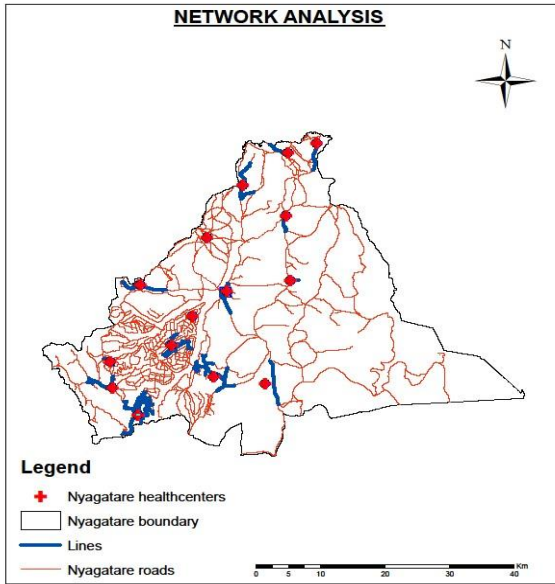


Figure 8: Standard travel distance

Figure 9: Minimum distance between

Households and facility

Travel time per patient was performed using ArcGIS software, the travel time based on the mode of transport, driving and walking. The network analysis tool was used to determine the distance and the time taken by the patients to have access to a health facility. With this analysis we observed that the patients who walk long distance to reach health center can walk 21Km in 4.2 hrs. whereas those who are near the health facilities can walk 0.001 Km in 0.0007 hours figure (11). With this

analysis, we assumed that patients are able to travel 5 km per hour. On the other hand, people who can have access to the health center by driving can reach the public health facility within 21,000 meters in 950 seconds (21km in 0.3hour) **figure (10)**. With this analysis, we used the article 29 regarding the speed and distance of vehicles in Rwanda which states that motorcycle and motor vehicles must cover 80 km/hr

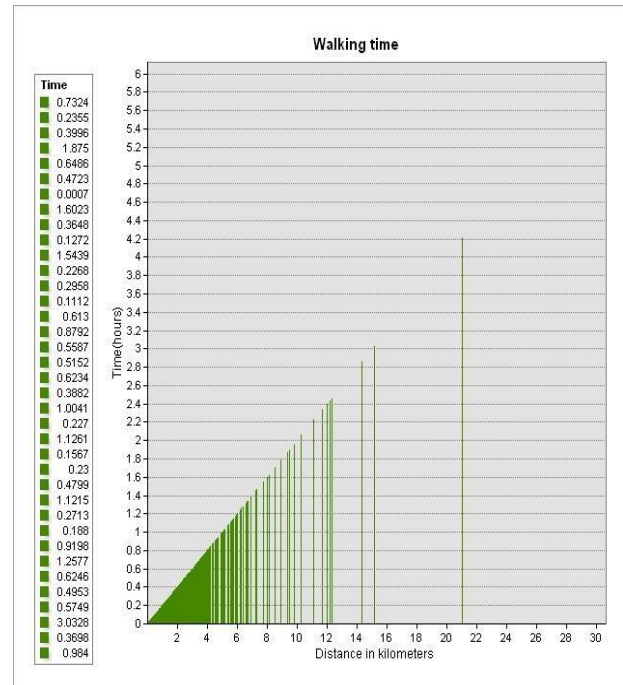
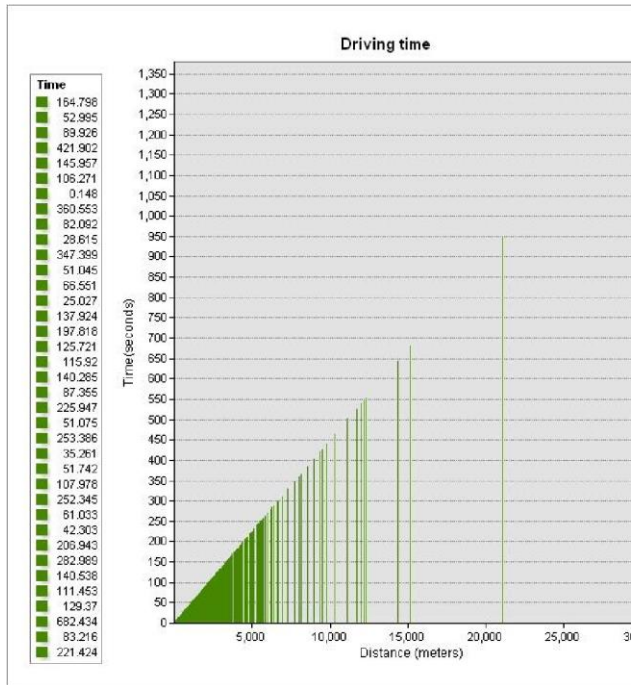


Figure10.Driving time to access nearest facility **Figure11.**Walking time to access nearest facility

Accessibility can be classified based on several issues, including availability, accessibility, accommodation, affordability, and acceptability (Bisht, Shailendra Singh, 2022). In addition, the availability of services, and barriers to access, have also to be considered in the context of the differing perspectives, health needs and socio-economic groups in the society. Health inequality in terms of accessibility come from several factors including location of health facility in terms of distance, cultural barriers such as traditional belief, affordability in terms of service costs or insurance due to poverty.

The result shows that the more populated areas such as urban areas in Nyagatare have more access to public health care facilities compared with rural areas, which is not different from what has been reported in other countries across the world (Mansour, 2016). People living in edge of village that fall behind 5 kilometers of walking as well as those living in remote and isolated areas face difficulties in access to health services (Hu et al., 2013). These parts should be given priority for future health center expansion plans made by local government and health planners in Nyagatare district.

IV. CONCLUSIONS AND RECOMMENDATIONS

The promotion of public health facilities plays a vital role in ensuring health delivery and wellbeing of community. Therefore, providing public health service based on population location is essential and simply a matter of social policy. Likewise, equity of health access and provision within urban areas require measuring several factors, such as availability, quality, travel, and distance from provider to population. Spatial modeling can provide insights into the access to healthcare facilities and will help inform policy decisions, as larger datasets can be processed quickly, efficiently and consistently. With this, it is possible to regularly assess geographic accessibility to health care services. Such regular measurement will identify poorly served locations due to population changes, thereby helping to know where a healthcare facility can be located to improve access. There is a need to measure accessibility with the incorporation data on poverty, population structure and capacity of healthcare facilities

to monitor access to health care, therefore creating a more robust indicator to support planning for health delivery for the district.

Nyagatare district leaders with help of planners should consider the distance and impedences before locating new public health facilities in order to promote accessibility at all to the provided facility. They must firstly provide some healthcare facilities to some areas which do not have any healthcare facilities in the most populated. These areas face difficulties of access in order to eliminate health inequality to all people need healthcare services.

Nyagatare district is flattened areas which may result into simple provision of healthcare facilities that can be accessed by everyone. What the government needs to do is to locate healthcare facilities closer to the neighborhood and in areas which can be easily accessed by traveling short distance and near the roads network. This should improve services provided to the patient and reduce some early deaths due to early get to health center.

References

- Bisht, Shailendra Singh, et al. (2022). Measuring Accessibility for Inclusive Development: A Census Based Index.” Social Indicators Research, vol. 98, no. 1, 2010, pp. 167–81. JSTOR, <http://www.jstor.org/stable/40783457>. Accessed 4 Jun. 2022. Journal of Health Services Research and Policy, 21(1), 36–39. <https://doi.org/10.1177/1355819615600001>
- Black, M., Ebener, S., Aguilar, P. N., Vidaurre, M., & Morjani, Z. El. (2004). Using GIS to Measure Physical Accessibility to Health Care. 1–22.
- Guagliardo, M. F. (2004). Spatial accessibility of primary care: Concepts, methods and challenges. International Journal of Health Geographics, 3, 1–13. <https://doi.org/10.1186/1476-072X-3-3>

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- Hu, R., S., D., Y., Z., H., H., & Z., L. (2013). Assessing potential spatial accessibility of health services in rural China: A case study of Donghai county. International Journal for Equity in Health, 12(1), 1–11. <http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed11&NEWS=N&AN=2013430348>
- Mansour, S. (2016). Spatial analysis of public health facilities in Riyadh Governorate, Saudi Arabia: a GIS-based study to assess geographic variations of service provision and accessibility. Geo-Spatial Information Science, 19(1), 26–38. <https://doi.org/10.1080/10095020.2016.1151205>
- Oliver, A. J., & Mossialos, E. (2005). Equity of access to health care. outlining the foundation for action.

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