



Accessibility Analysis of Childbirth Service Centers Using Geospatial Techniques in Rural Magadi, Kenya

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Abstract

Accessibility to childbirth services is a necessity despite geographic, demographic and socio-economic origin. The distribution pattern between health facilities and households in rural areas is not as extensively researched as those of urban areas, especially pastoral communities. Challenges in accessing social amenities including childbirth service centres are dominant. This study aims to assess the spatial accessibility between the location of households and the location of the childbirth health facility in Magadi Ward. The study employed geospatial techniques to visualize the spatial distribution of households and health facilities; and the road connectivity between them. To represent the variation, accessibility zones were modelled using the Euclidean distance tool. Buffer analysis was also conducted to indicate the relationship between the served and unserved areas in regard to the five kilometres Ministry of Health recommended radius. Coordinates of 246 households were randomly picked from the eight community unit clusters in the Magadi ward. The findings revealed the number of women who delivered at health facilities to be 38.2%, while those who delivered at home were 61.8% contrary to the majority being within the service area of the buffer. The most accessible zones were located in the central and upper western parts of Magadi Ward. The utilization of antenatal and postnatal care services and health facilities for the place of delivery differed significantly. The results indicate the poor use of health facilities as a place of delivery for women who utilized childbirth services in the last year, prior to data collection. This provides valuable information and location-based evidence of low access to health facilities for childbirth services, and therefore, offers guidance on sound decision making and strategies to improve on the accessibility of childbirth services.

Keywords: *Accessibility; Childbirth; Geospatial; Health facilities; Magadi*

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Introduction

Accessibility is referred to as the spatial relationship between the location of supply and demand (Penchansky and Thomas 1981; Saurman 2016). In healthcare services, it is a major component of assessing the distribution of health facilities and determining areas of poor accessibility (Gao and Kelley 2019) for both primary healthcare (PHC) services and centralized specialist care (Mcgrail and Humphreys 2014). Poor accessibility is particularly evident in rural community settings, especially in sub-Saharan Africa which is majorly dominated by third world countries; with Kenya among the list. Childbirth services, which in the context of this study is defined as services a woman receives from the time she conceives and extending to six months after birth. In Kenya, according to the demographic and health survey, 61% of child deliveries took place in health facilities as of 2014 (National Bureau of Statistics Nairobi 2015). Similarly Mbugua and MacQuarrie (2018) in reporting the Kenya Demographic Health Survey findings established that high inequalities in the distribution of childbirth services especially delivery care; and also ante-natal care (ANC) and post-natal care (PNC). The report further indicated that at county levels, disparities are commonly due to urban-rural residence among others. According to this report, Turkana County, which is inhabited by pastoralists just like Magadi Ward in Kajiado County has low health facility deliveries due to place of residence Mbugua and MacQuarrie, (2018).

Furthermore, the numbers continue to dwindle when it comes to rural areas due to the underutilization of childbirth services. This is because childbirth service is a form of primary

healthcare service that is compromised in rural areas due to multiple factors such as geographical variations, road network, lack of proximal health service centres and choice of economic activity, which in turn affects a woman's residence; among others. To minimize the effect of these factors, the location of health facilities must be considered carefully if the services are to be proximal/accessible by the target community (Maina *et al.*, 2019). Despite many factors being associated with childbirth service utilization, the physical distance was a major concern in Kenya (Moindi *et al.*, 2015).

To improve on physical accessibility, the Government of Kenya recommended that populations be located within a five kilometers radius of a health facility so as to be termed accessible to services (Ministry of Health Kenya, 2014a, 2014b). Nonetheless, population density determines the location of a health facility. In rural areas, the distribution of the population is skewed. Thus, the case for marginalized communities such as pastoralist communities are characterized by sparse population and low access and use of childbirth services such as the Maasai people of Kenya. Poor access and use of childbirth services is associated with poor childbirth outcomes such as high maternal mortality rate (MMR), high neonatal mortality rate (NMR), increased infant mortality rate (IMR) and low birth weight (Hug *et al.*, 2018). These are economic obstacles affecting attainment of sustainable development goals especially SDG 3, SDG 11 Vision 2030 and the Big four Agenda. The spatial disparity of health facilities is a critical reason for unequal access to health outcomes. In rural communities like Magadi in Kenya, road conditions between households (HH) and HFs are determining factors of accessibility to

childbirth services (Iimi and Bank, 2021) . The stretch between the households and the health facilities is not well documented in these pastoral regions. The communal ownership of land further makes it difficult for development strategies to be undertaken. The existing road network connectivity provides a basis for the mapping since access to childbirth services is a direct function of road transport connectivity and distance to service area.

Using geospatial techniques, this study seeks to examine spatial access from households to health services as well as mapping their locations. The motivation for this paper is to inform location-based evidence of low access to health facility childbirth services, and therefore, accordingly guide in sound decision making and strategies to improve on the accessibility of childbirth services. The study specifically assessed the spatial location of households and health facilities in the Magadi ward vis-a-vis the access and use of childbirth services.

Materials and Methods

The study was conducted using a descriptive cross-sectional research design. The study area, datasets and data collection and analysis procedures are described below.

Study area

The study was conducted from April 2020 to April 2021 in Magadi Ward one of the four administrative wards in Kajiado west Sub-County, Kajiado County in Kenya, Figure 1. It lies approximately at longitude 1.90° N and latitude 36.30° E and is situated at an altitude of about 600m (Kyuma *et al.*, 2016) (Figure 1). The ward shares boundaries with Narok County to the West, Tanzania to the South, Iloodokilani and Keekonyokie wards to the East and Mosiro

and Esonorua wards to the North, Figure 1. It has a bimodal rainfall pattern with an annual total of 460 mm and a mean of 50 mm, with mean temperatures of 32°C (Kyuma *et al.*, 2016). The landforms are composed of plains, plateaus, low gradient foot slopes, medium gradient hills and occasional high gradient hills (Gregorio and Latham, 2002). The slopes range from flat gently undulating, rolling and steep slopes with sparse vegetation and bushlands (Gregorio and Latham, 2002). This climatic condition has led to the Ward being classified as arid and semi-arid region; thus, supporting the semi nomadic pastoralism being practiced as the main economic activity.

The Ward is zoned into eight (8) community units namely: Oldonyo Nyokie, Musenge, Entasopia, Olkiramatian, Pakase, Shompole, Oloika, and Magadi (Figure 1). According to the 2019 nationwide census report, the ward has a total land area of about 2,563 km² with 7,523 households distributed in the area. The Ward has a total population of 33,264 persons; and out of this, 16,467 were the total number of females without regarding the age category (Kenya National Bureau of Statistics, 2019). The relatively sparse population in the region compared to other non-pastoral regions characterizes the area as having low population density.

For this research, sampled households must meet the minimum criterion that there must be at least one woman of childbearing age who gave birth in the last one year by the time the research was conducted. From literature, the latest study conducted on access to health facilities for deliveries in Magadi ranked the region at a 39 % childbirth rate (Karanja *et al.*, 2018).

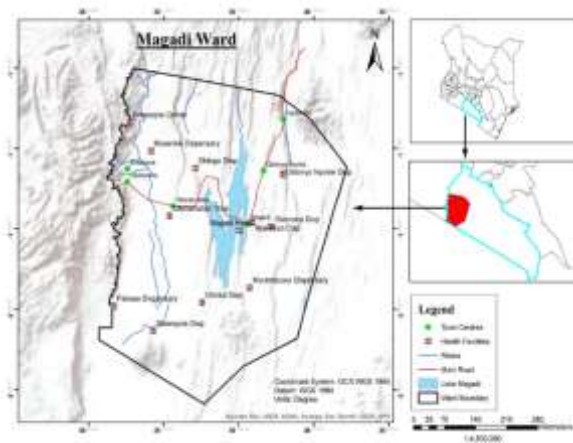


Figure 1. Location of Magadi in Kajiado County, Kenya

Health Facility Data

Health facility coordinates were collected using a mobile app and the Garmin GPS and the points mapped on ArcMap 10.5. The select by location tool was used to identify facilities that fell slightly off their correct locations and ward boundaries. Tentatively, GPS coordinates are expected to specify a unique spatial location, these required careful re-assessment to ensure that facility locations were on their true position on the earth's surface. A health facility census included picking locations of 16-dispensaries/clinics, one health centre and one level-4-hospital (Magadi Hospital) in the area.

Households Data

The coordinates for sampled households were also handpicked using a mobile app and Garmin GPS and the points mapped on ArcMap 10.5. The total population size of women of childbearing age in Magadi was unknown. Our confidence interval was 95% with a margin of error $\pm 5\%$. Therefore, Yamane's formula (Yamane, 1967) was used to obtain a 274 sample size. Multi-stage sampling was applied to sample out women from the unknown target population of women of childbearing age. This was achieved by first

considering the eight community units of the Boma model by AMREF (AMREF, 2013) as clusters, so as to achieve the geographical variance of the challenges to access and use of childbirth services in Magadi Ward. At the stage of community units, the population was further split into sub-clusters called villages where women who gave birth in the last year were proportionately picked from the households using systematic random sampling. Out of the 274-sample size, 246 women responded to the study giving a response rate of 89.8%.

During mapping of the household coordinates, some six houses were plotted in wrong community units and were correspondingly validated, reassessed and verified. These were assigned new coordinates based on the household unique IDs (allocated based on the community units) using Google Earth and minor shifts made in the ArcGIS software.

Women from the sampled households were also interviewed to capture their place of delivery and whether they used both antenatal and post-natal care services and the responses recorded.

Road Network Data

Road network data was sourced out and digitized from Google Earth Pro 7.3. The data was then exported to ArcMap 10.5 for projection to the local datum (Arc 1960 UTM Zone 37S) and further manipulation. Topology was run on the roads to correct for undershoots and overshoots thus ensuring connectivity. Each road segment was accompanied by geometric information which was stored in the attribute table. The roads were composed of major roads (Magadi road) and minor roads.

Data Management and Analysis

This section describes the methodology applied to the multi-source data used in this research (Figure 2). The area was mapped using the sub-locations as the baseline representing the eight community units where the sampled data was collected. Data collected using the GPS was downloaded into an excel file for further manipulation. The excel file was imported into ArcMap 10.5 as a comma-delimited (CSV) format and using the X and Y function; the data was plotted for visualization. All the datasets were then re-projected into the same coordinate system (Arc1960 UTM Zone 37°S) which is a local datum for proper alignment. They were later on exported as shapefiles which were then imported as feature classes in a geodatabase. To further understand the distribution of healthcare facilities vis-à-vis household data, a 5-kilometre buffer was calculated around each health facility irrespective of the type and level to determine the service area of a health facility according to the Ministry of Health (MoH) guidelines. The results of this section are presented by Figure 4.

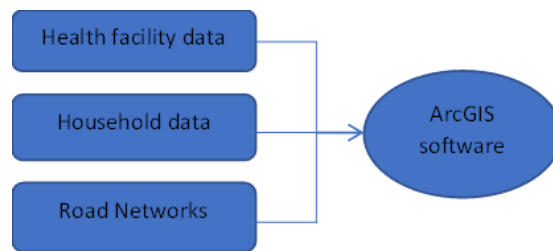


Figure 2. Framework for data sets

Results

Distribution of Households, Health Facilities; and Road Network Connectivity in Magadi Ward

Mapping presented a total of 18 health facilities which were distributed across the Ward. Out of the 18 health facilities in the area, 12 offered childbirth-related services. Table 1 shows the distribution of the 12 health facilities offering childbirth services across the eight community units in the Magadi Ward. The majority of the health facilities are level 2, with only one level 4 servicing the entire Ward; and even beyond. From the 246 sampled households, 152 (61.8%) women from 152 households reported delivering at home while 94 (38.2%) of women reported delivering at health facilities. In addition, 201 received antenatal care and post-natal care services in a health facility as illustrated in Figure 3.

| Community Units (8) | HF present | Type of HF | No. of Sampled women/Households | Nearby Road type |
|---------------------|---------------------------|------------|---------------------------------|------------------|
| Entasopia | Entasopia Health Centre | Level 3 | 14 | Murram road |
| Olkiramatian | Olkiramatian Dispensary | Level 2 | 50 | Murram road |
| Oldonyo Nyokie | Oldorko Dispensary | Level 2 | 39 | Murram road |
| | Oldonyo Nyokie Dispensary | Level 2 | | Tarmac road |
| Pakase | Pakase Dispensary | Level 2 | 16 | Murram road |
| Shompole | Shompole Dispensary | Level 2 | 47 | Murram road |
| Magadi (Olkeri) | Magadi Hospital, | Level 4 | 40 | Tarmac road |
| | Ilparakou Dispensary | Level 2 | | Murram road |
| | Murantauwa Dispensary | Level 2 | | Murram road |

| | | | | |
|--------------|--------------------|---------|------------|-------------|
| Musenge | Musenge Dispensary | Level 2 | | Murram road |
| Oloika | Oloika Dispensary | Level 2 | 36 | Murram road |
| | | Level 2 | 4 | Murram road |
| Total | | | 246 | |

Table 1. Number of sampled women/households per community unit and nearby Health facilities (HF) that offer childbirth services.

The sampled households and the health facilities are connected using existing digitized road networks. The roads were customized based on motorability and surface feature, leading to trunk and feeder road categories: Trunk roads which are partly tarmacked and are motorable whereas feeder roads are murram as they are without tarmac; and are also barely motorable. Majority of the roads connecting health facilities in the Ward are murram roads: un-surfaced feeder roads that are non-all weather hence, not motorable during the rainy season. This could be among the reasons for the low access and use of childbirth services by women in Magadi Ward. The conditions of the roads are generally poor in the ward and the transport means (both public and private) are rare (Figure 3). The commonly used; and available mode of transport is either by foot or use of motorcycle.

The digitized roads were categorized into two classes: major roads (Class C) and minor roads (unclassified). In Magadi Ward, there is only class C road, namely Magadi Road, which enters the Ward through Oldonyo Nyokie community unit (Oldonyo Nyokie location), to Magadi town, joining Olkaramatian East location through Lake Magadi course ways and finally to Olkaramatian West ending at Nguruman escarpment (Figure 3). This road is tarmacked (all-weather) up to Magadi town after which the rest is murram (non -all-weather). Health facilities that lie along Magadi Road include Oldonyo Nyokie Dispensary and Magadi Hospital. Minor roads, also called the feeder roads, are the roads that join or branch off the major road. Minor roads originate from the households to the health facilities or to the main road, all of which are non-all-weather roads; with majority of the health facilities located at the junctions of minor roads within the Ward (Figure 3).

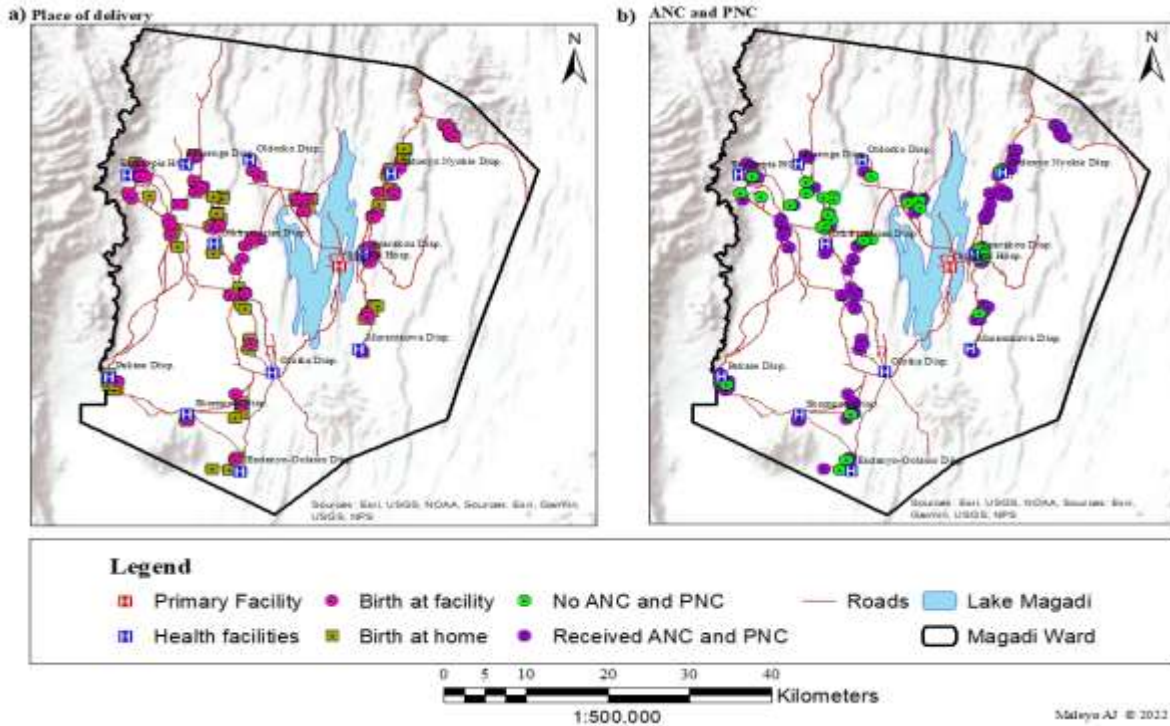


Figure 2. a) Spatial distribution of households and health facilities offering childbirth services and road connectivity to the place of delivery in Magadi Ward, b) Spatial distribution of households and health facilities offering childbirth services and road connectivity to utilization of ANC and PNC in Magadi Ward

Spatial Analysis of Accessibility using Buffer Tool and Euclidean Distance

The five-kilometer radius buffers created around health facilities offering childbirth services were presented and households within the service areas quantified (Figure 4). Accordingly, 151 (61.4%) of the households of sampled women were located within the service areas (which are also defined as the areas within the five-kilometer radius, as per

the Kenyan Ministry of health recommendation), out of these households, 107 (70.9%) gave birth at home while 44 (29.1%) gave birth at health facilities. Correspondingly, the total number of women who utilized both antenatal and post-natal care services were 201, those living within the service area that is, within the 5km buffer were 151, out of which 123 (81.5%) received both ante natal and post-natal care services and 28 (18.5%) did not receive both ante natal and post-natal care services (Figure 4).

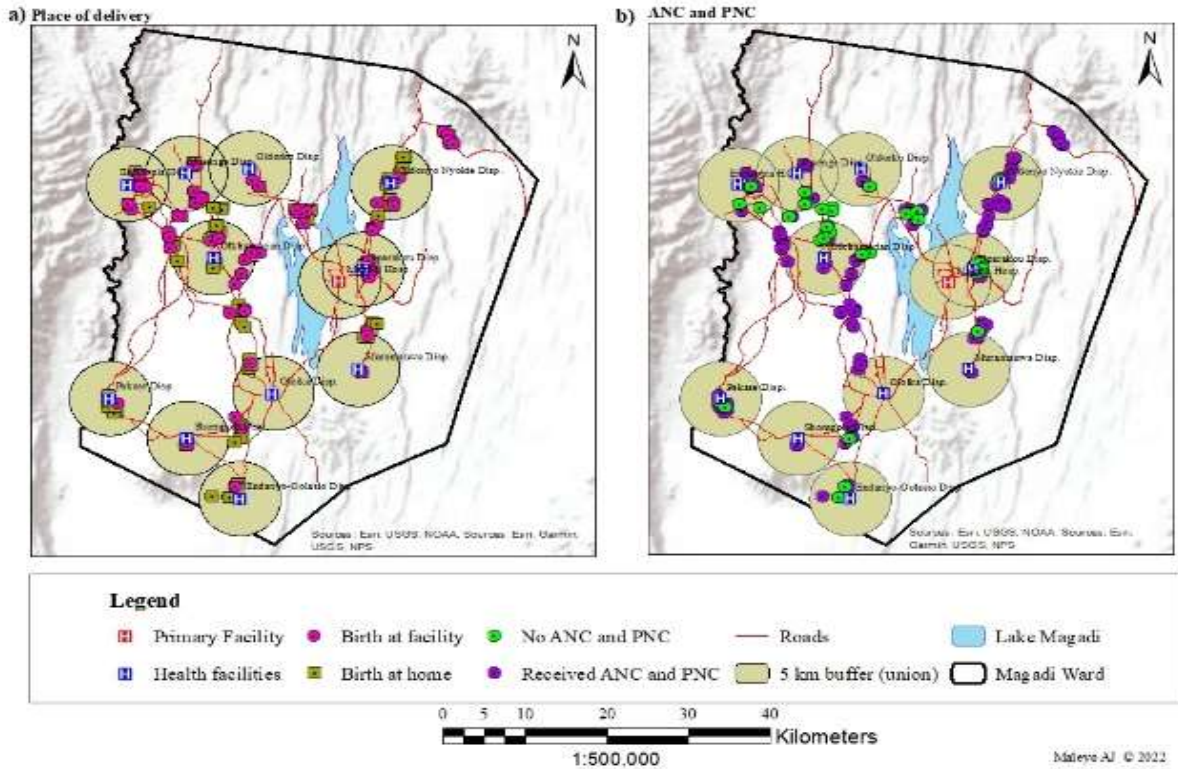


Figure 3. a) Spatial accessibility of place delivery within the 5 km radius of health facilities offering childbirth services using a buffer in Magadi Ward, b) Spatial accessibility of ANC/PNC within the 5km radius of health facilities offering childbirth services using the buffer tool in Magadi Ward

To further illustrate this, a surface distance was created using the Euclidean distance tool. This is intended to describe the accessibility and usability of health facilities in Magadi vis-à-vis place of delivery; and utilization of ante natal and post-natal care services. The process led to the classification of the health facility accessibility into three categories: High accessibility (green), Moderate accessibility (yellow) and Low accessibility (Red) (Figure 5). High access areas are designated by green colour to mean surfaces that are easily accessible and usable by the women for childbirth services. These are areas that have closer proximity to the health facilities. According to the results in Figure 5, the majority of the population resides here. For example, the North West, where it is highly concentrated because of clustering of health facilities. Moderate access areas are designated

by yellow colour to mean surfaces with intermediate accessibility, in other words, a transition between high and low access, by the population to the health facilities. These are areas with average proximity to the health facilities. A handful of the population is found here, for example, in some Lengobei areas, between Oloika and Shompole areas, between Magadi and Murantauwa, between Magadi and Oldonyo Nyokie enclaves. Low access areas are designated by red colours to imply surfaces with low accessibility and usability of health facilities by the population. These are areas that are far from health facilities. A minority of the people reside here. For example, between Oldorko and Oldonyo Nyokie, between Oldorko and Magadi, parts of Lengobei, between Olkiramtian and Pakase, areas between Pakase and Nguruman, South Eastern and Oloika surroundings.

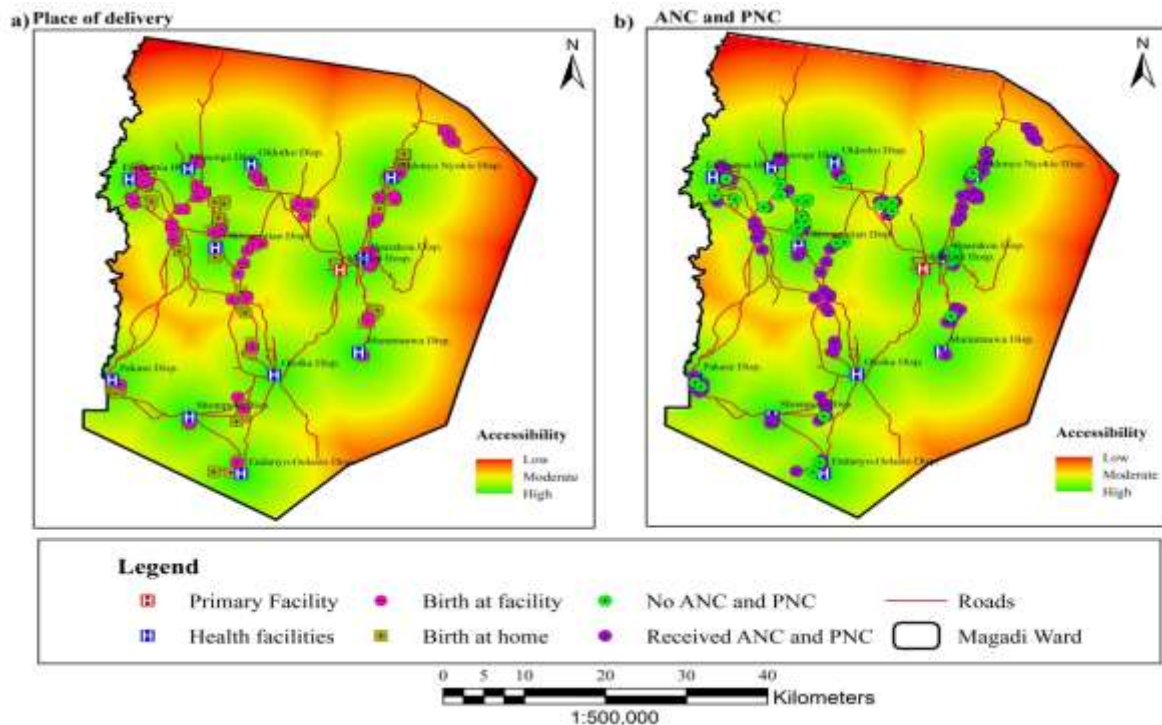


Figure 4. Spatial accessibility index of childbirth services in Magadi Ward using Euclidean distance (a) in place of delivery and (b) ANC and PNC

Discussion

This study analysed the geographic distribution of health facilities and households in relation to the access and use of childbirth services in Magadi Ward. Geospatial techniques were used to visualize and describe the characteristics of the association amongst the datasets. Though most women were within the five kilometers radius service area, accessibility to childbirth services varied from category to category. For the place of delivery category, most women located within the five kilometers service area did not use health facilities for child delivery services; whereas those women who utilized antenatal and post-natal care childbirth services were mostly located within the service area. This variation in uptake of childbirth services could indicate the multidimensional effect of accessibility even within the service categories. To explain this variation, child delivery as a service

presents options for both health facilities and home deliveries, hence, women make convenient choices, unlike antenatal and post-natal care services where immunization and growth monitoring is only administered solely by government through a health facility by a competent staff. As a result, interventions towards improving the use of health facilities for child delivery services such as establishing maternity waiting homes, improving the transport network, among others should be designed to encourage women to use health facilities for child delivery.

This finding is contrary to the Ministry of Health recommendation which presumes that individuals within a five kilometer radius of a health facility would access and use health services including childbirth services unlike those outside (Ministry of Health [Kenya] 2011, 2014a, 2014b) and also Escamilla and others (Escamilla *et al.*, 2019) who when generating distances between public hospitals and

household clusters who apart from revealing that most households that utilized primary care were within five kilometer radius of a health facility, assumed that this proximity translated to an automatic use of health care services. Additionally, it also contrasts with the study by Karanja and colleagues (Karanja *et al.*, 2018) that examined factors influencing health facility deliveries in the Maasai community, and which indicated that distance is a factor affecting use of health facilities for delivery. It also contrasts with the results by Ettarh on the place of delivery; but, corresponded with antenatal and post-natal care services utilization. Ettarh in using reported distance from the 2008-2009 Kenya demographic health survey, established that women who resided 5km or less from the nearest health facility were more likely to deliver in a health facility than those who live far (Ettarh and Kimani, 2014). Similarly, these results are also inconsistent with results from a study in Ghana that modelled the influence of distance in utilizing birthing services. This study did not only reveal that women in rural areas travelled 4 km more than urban women to reach a hospital; but also discovered that an increase in distance by one kilometer significantly decreased the number of women delivering at health facilities by 6.7% (Gborgbortsi *et al.*, 2020). The apparent contrasting finding can be attributed mainly to the availability of options for place of delivery service category; and further, it can also be explained by difference in population and culture.

The study further illustrated the inaccessibility of quality childbirth services in Magadi Ward applying a five-kilometer buffer around the only primary facility in Magadi (Magadi hospital). From the display, only a small percentage of the sampled households were

within the buffer service area of the primary facility. Since the primary facility is the only facility able to offer advanced childbirth services as well as handle childbirth complications in Magadi; this means the Ward is highly underserved with quality childbirth services. Interventions towards increasing the number of primary facilities is encouraged if optimum access to quality childbirth services is to be realized by all women of childbearing age in Magadi Ward. This corresponds to the outcomes analyzed in Mozambique where in which the geographical access to primary health care centers was assessed. Majority of Mozambicans are located in underserved thus making their utilization of primary health care services poor (Luis and Cabral, 2016). On the contrary, the results of a study conducted in Malawi do not concur with this finding. This study by (Kim *et al.*, 2019); reported that notwithstanding distance band and place of delivery, utilization of both maternal and neonatal post-natal care did not bear significant positive effects.

A reliable picture of women mobility on existing routes through the digitized roads in Magadi, a marginalized rural community was provided. The findings showed that accessibility through the road network is poor due to the area's dominance by non-all-weather minor roads. This may be attributed to the fact that all these roads are non-all weather except a section of Magadi Road and also to note is the generally low terrain in Magadi area; thus, posing restrictions on movement especially during wet seasons. The findings on the road network details in Magadi calls for interventions by both the central and the county governments to prioritize the allocation of resources towards designing proper and motorable (tarmacked) roads and ultimate

planning of a referral transport system to ease access to childbirth services. This finding is similar to the result from a policy research working paper by the Global Transport Practice on estimating the effect of improving road accessibility as evidenced from Mozambique; which determined that transport connectivity to health facility is a significant factor for access to health care services in the rural parts of Mozambique (Iimi and Bank, 2021). Just like the case in Magadi Ward, Kenya, the results further stated that rural Mozambique is also dominated by feeder roads, whose liability for maintenance does not rely on government funds (Iimi and Bank, 2021). The research also concurs with results from a systematic review study on barriers to access and utilization of emergency Obstetric care (EMoC) at health facilities in sub-Saharan Africa which established that poorly designed roads were among the factors that cause delay inaccessibility to health services (Geleto *et al.*, 2018). To add, the finding is also significant to the implementation and the achievement of the sustainable development goal eleven (SDG 11.1), access to transport system for all; and further indicating its proposal for access to all weather roads by the year 2030 (Davies, 2015) Euclidean distance portrays Magadi Ward into three accessibility zones. Despite most women falling into the high accessibility zone, most of them gave birth at home while, contrastingly, most of them combined ANC and PNC. This could be attributed to the fact that child delivery is a service that presents as an emergency, unlike ANC and PNC that can be rescheduled to a convenient time. Since Euclidean distance ignores physical obstacles, this possesses a challenge to women during the onset of labour when such factors are put into consideration. Interventions towards increasing road connectivity to enable women

to give birth in a health facility should be increased. Euclidean distance surface cells and linear metrics concur with linear metrics obtained from the 5 km recommendation from the ministry of health, that after every five kilometers, there should be a health facility (Ministry of Health Kenya, 2011, 2014b) (Figure 5). This study also compares with findings from a South African study on new approaches on spatially analyzed usage of primary health care that indicated that straight-line distances do not take into account physical obstacles (Tanser *et al.*, 2001). Therefore, it illustrates that Euclidean distance is not ideal in understanding the spatial usage patterns of health facilities.

Conclusion

The main aim of this paper is to assess the access and use of childbirth services using geospatial techniques. This research discussed accessibility zones of Magadi Ward to illustrate some of the challenges involved in the spatial accessibility to health facilities. The spatial association that exists between the location of HH and HF and poor road network are among the causes of low access to childbirth services. The usefulness of this study is its ability to capture the accessibility to childbirth services and relate it with road connectivity. The results highlight the widespread disparities in access to health facilities by the participants in rural Magadi. Thus, the outputs can provide useful insights into where gaps in accessibility are, and decision-makers can know where to narrow down to if service expansion is needed (Ouma *et al.*, 2021).

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