Geographic Assessment of Telecommunication Signals in a Mining Community: A Case Study of Tarkwa and its Environs*

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Boye, C. B., Peprah M. S. and Kodie N. K. (2018), "Geographic Assessment of Telecommunication Signals in a Mining Community: A Case Study of Tarkwa and its Environs", *Ghana Journal of Technology*, Vol. 2, No. 2, pp. 41 - 49.

Abstract

Millicom Ghana Limited is one of the leading telecommunication network companies in Ghana whose core vision is to be the best service provider in the urban/rural areas. However, Tigo experienced a reduction in their monthly growth assessment in both voice and data subscriptions in 2016. To curb the dwindling subscriptions, it has become necessary to investigate the actual quality of signal strength available to customers of Tigo in spatial context, and to make recommendation for improvement. Primary and secondary datasets were used for the study. The field data comprises of mobile phones signal strength measured at systematically sampled locations whose coordinates were measured with handheld GPS receivers. Digital Elevation Model of Tarkwa and its environs, coordinates of cell towers and georeferenced image of Tarkwa and its environs were also used. Buffer analysis was performed to determine the area coverage of the mounted cell towers. Viewshed analysis was done to determine the visibility of cell towers in the study areas. Through the process of interpolation and overlay analysis, a signal strength map of the study area was generated. Results obtained showed varying degree of signal strengths in the study area with low signals predominant in Akyempim and some portions of Nsuta and New Atuabo while cash zone areas (areas with higher signals) were found to be predominant in Tarkwa, Tamso and some portions of New Atuabo. Based on the results, it was recommended that, Tigo management should plan an extension of cell towers in Akyempim, New Atuabo and Nsuta to improve signal transmission and quality service to customers.

Keywords: Telecommunication Signals, GIS, Viewshed Analysis, Digital Elevation Model

1 Introduction

The dissemination of information for socio-economic development of a country has been one of the major tasks among geospatial and non-geospatial professionals (Jones, 2009). The essence is to create an interactive community and to promote propagation of scientific research findings (Odunola *et al*., 2015). This is because a great community is characterised by efficient dissemination of information to its citizens (Omogunloye *et al*., 2013). However, dissemination of information in some areas of interest is still a challenge particularly, in some mining communities (Sawada *et al*., 2006; Guoray, 2002). As a result, several researchers have proposed different methodologies to aid in dissemination of information in order to improve the quality of life of people (Naveenchandra *et al*., 2011; Al-Hamani and Hashem, 2011).

Dissemination of information in real time to citizens is usually through voice mails or internet. Signals are often transmitted in the form of waves from the device of the transmitter to that of the receiver. For effective information dissemination, both the transmitter and the receiver devices must have high quality signals. Electronic gadgets such as laptops and mobile phones are devices most commonly used in telecommunication. Some of the mobile phones service providers in Ghana include Mobile Telecommunication Network (MTN), Vodafone Mobile, Bharh Ghana Limited (Airtel), Glo Mobile, and Millicom Ghana Limited (Tigo).

Tigo is one of the leading telecommunication network companies in the study area. However, statistics from the Ghana National Communication Authority (NCA), indicated growth retardation in Tigo's telecom voice subscriptions in 2016 (Anon., 2017). To mitigate the dwindling subscriptions of the company, a merger between Tigo and Airtel has been proposed which has been approved by NCA in 2017 (Anon., 2017). It has become necessary therefore to investigate the actual quality of signal strength available to customers of Tigo in the study area in spatial context, and to make recommendation for improvement.

GIS is a tool that combines spatial and non-spatial information to promote visual thinking, facilitate effective decision making and could be employed in the assessment of telecommunication signals (Jones, 2009, Wilson *et al*., 2016; Boz, 2016; Isong and Umoh, 2015; Hart *et al*., 2012). Some GIS applications include: assessment of telecommunication infrastructure (Guoray, 2002), distribution of cell towers (Al-Hamani and Hashem, 2011; Omogunloye *et al*., 2013), signal strength measurements and coverage estimation of mobile communication network (Naveenchandra *et al*., 2011), and telecommunications mast location and its health implication for residence (Odunola *et al*., 2015). These researchers found GIS as an effective

**Manuscript received December 15, 2017*
Revised version accepted March 19, 2018

tool that helps telecommunication professionals to make informed decisions through spatial analysis to improve upon their services. GIS approach was therefore adopted to access the strength of the signals in the present study.

The study aims to assess the signal strength in the study area and to investigate the spatial factors that contribute to black spots within the area of interest. Recommendations from this study would help improve signal strength thus enhancing their service delivery.

1.1 Study Area

Tarkwa is a mining community located in the Southwestern part of Ghana (see Fig. 1). It lies on latitude 5º 18´ 00″ N and longitude 1º 59´ 00″ W with average topographic elevation of about 78 m above mean sea level (Peprah *et al*., 2017). The area has a total land cover of about 905.2 km^2. The lands are generally undulating with steep slopes. The area is about 90 km away from Sekondi-Takoradi, the regional capital of Western Region by road and about 288 km west of Accra, the capital of the Republic of Ghana (Adjei, 2016). The town is noted for mining of gold and manganese which contributes significantly to the economic development of Ghana. It hosts five of the major gold mining companies in the country and several small-scale mining companies. The influx of job seekers to the area gives it a characteristic population distribution of males slightly out numbering females, a ratio higher than the national value (Eshun and Mireku-Gyimah, 2002).

2 Resources and Methods Used

2.1 Resources

This study used primary and secondary data. The secondary data included positions of cell towers (Masts) positions in the study area, georeferenced satellite image of the area and topographic map of the area. Mobile phones (with the Tigo SIM card) were used to measure the signal strengths at sampled sites within the study area while the coordinates of the sites were measured with handheld GPS receivers. The mobile phone was adopted to determine Tigo network strength within the study area due to unavailability of radio frequency electromotive force (EMF) strength meter. Besides, this method of measuring mobile phone signal strengths values was implemented because it is less costly and offers a simple approach to signal strength measurements (Madara *et al*., 2016; Shankari *et al*., 2014).

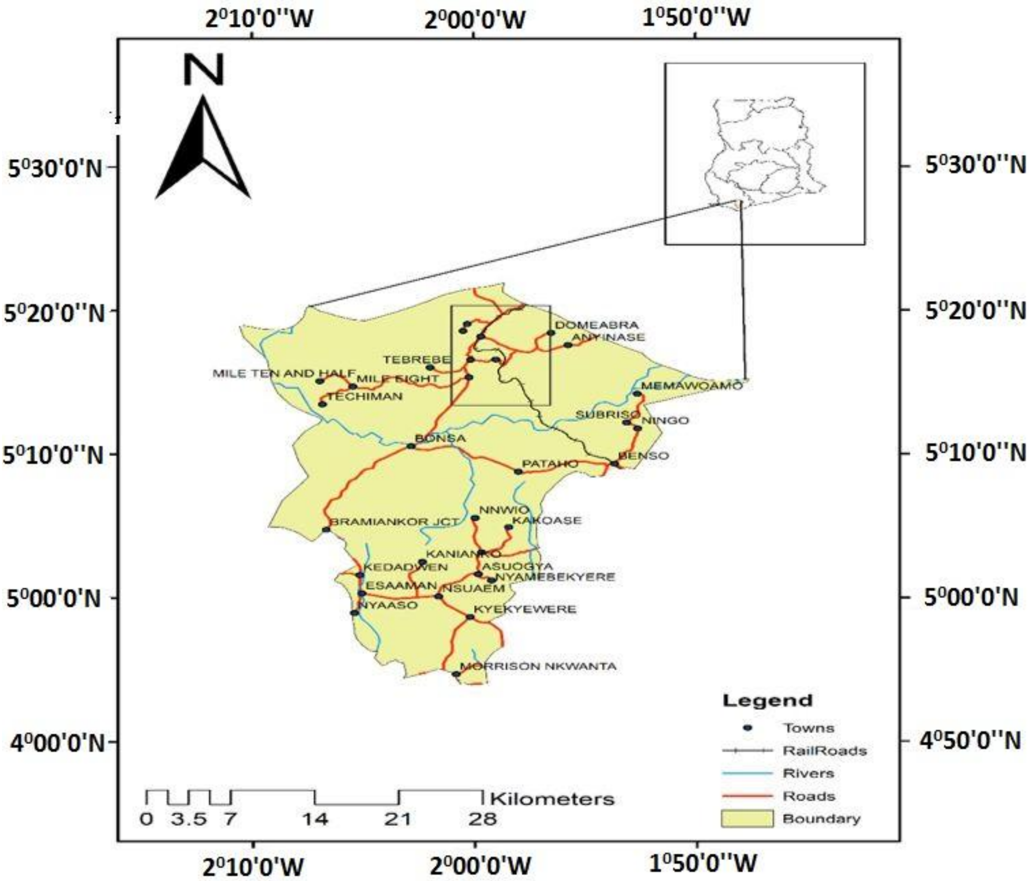

Fig. 1 Study Area

2.2 Methods

2.2.1 Systematic Sampling

Systematic sampling using a grid interval of 500 m was carried out in ArcGIS environment and the signals were measured at each grid intersection point. Grid interval of 500 m was chosen as it provides fair representation of the topography as well as allow significant variation in the signal strength values to be mapped. Systematic sampling technique was also adopted because it is the most practical method of sampling spatial phenomenon since signal strength spreads more evenly over the geographic space under consideration. Systematic sampling is easy to carry out, convenient, yields unbiased representative of the sample space, statistically economical and widely used sampling approach (Acharya *et al*., 2013; Bluman, 2012; Bellhouse, 2005).

2.2.2 Measurement of Sampled Locations and Mobile Phone Signals Values

Setting out of extracted coordinates from the geo-referenced image of the sampled grid intersection points were uploaded into the handheld GPS receivers. The uploaded coordinates were tracked using the waypoint feature approach of the Handheld GPS receiver. Hence, the Mobile phone signal strength values (*i.e.* 0-1-2-3-4) were measured at these locations.

2.2.3 Buffer Analysis

All the cell masts in the study area have a radius of coverage of 62 km. Hence a buffer of 62 km was created around each of them to determine areas which are likely to receive signals from the cell towers. The creation of buffer determines the network coverage in the study area. Those within the coverage area are expected to have strong and effective network signals for quality communication (Burrough and McDonnell, 1998; Kang-Tsung, 2008; Heywood *et al*., 2004).

2.2.4 Viewshed Analysis

Viewshed analysis was performed to determine areas in the study area which are visible from the masts. These areas are expected to receive signals without obstructions from the terrain or physical object such as buildings. The following factors were considered in the viewshed analysis: height of cell towers which is 60 m above mean sea level; radius of coverage of masts which is 62 km and terrain elevation of the study area. In this study the viewshed analysis allowed the author to assess the parts of the study area that have high probability of receiving mobile phone signals (Casagrande *et al*., 2016; Petrasova *et al*., 2015; Wheatley, 1995).

2.2.5 Interpolation by Inverse Distance Weighting

Interpolation by Inverse Distance Weighting (IDW) method was performed to predict mobile phone signal values for unsampled sites based on the sampled point values in the study area. This technique was used in the study because it is simple, easily understood and it yields accurate estimates once the sampling is sufficiently dense with regards to the local variation being simulated (Chen and Lui, 2012). IDW is a deterministic interpolation technique often used for spatial analyses; it assumes that the attribute value of an unsampled point is the weighted average of known values within the neighborhood (Robinson and Metternicht, 2006; Lu and Wong, 2008; Chen and Lui, 2012). The weights are inversely related to the distances between the prediction location and the sampled locations. In the interpolation method, if *y* value of reference points (*i.e.* signal strength values) have been determined, then the signal strength of any intermediate point (s) in the constructed model is found by moving on *m* number of reference points around that point by using Equation 1:

$$s_i = \frac{\sum_{i=1}^{m} y_i P_i}{\sum_{i=1}^{m} P_i} \qquad (1)$$

where S_i indicates the signal strength to be calculated by interpolation, y_i indicates the signal strength of the reference points around the point whose signal strength is to be calculated by interpolation, P_i represents the weight values of the reference points and m represents the number of reference points to be used in interpolation (Ayer *et al*., 2016; Gullu *et al*., 2011; Ziary and Safari, 2007).

2.2.6 Overlay Operation by Intersection

Overlay operation by intersection was carried out to combine the viewshed output features which overlaps with the output features of the interpolation to obtain the final signal map. This was done to enable a map showing the signal strength to be produced. The final output map represents the varying degrees of signal strengths in the study area.

3 Results and Discussion

3.1 Results

Fig 2 presents a georeferenced image of the study area, showing the built-up portions (building and roads) as well as positions of cell towers that provide signals to users of the Tigo mobile phones network. Most development seem to be concentrated along the Northeast through the central part to the southwest. Four out of the five cell towers in the study area are sited in this zone.

Figs 3 and 4 show the results of the 62 km coverage area buffer, and the output of the assessment of inter visibility between sampled sites and the cell towers through the viewshed analysis. The results of IDW interpolation of sampled signal strength values is a continuous dataset of signal strength of the entire study area presented in Fig 5. Whereas a classification of signal strength adopting Tigo's colour code is presented in Table 1. Fig 6 shows the final Map indicating the signal strength of Tigo mobile phone network in the study area.

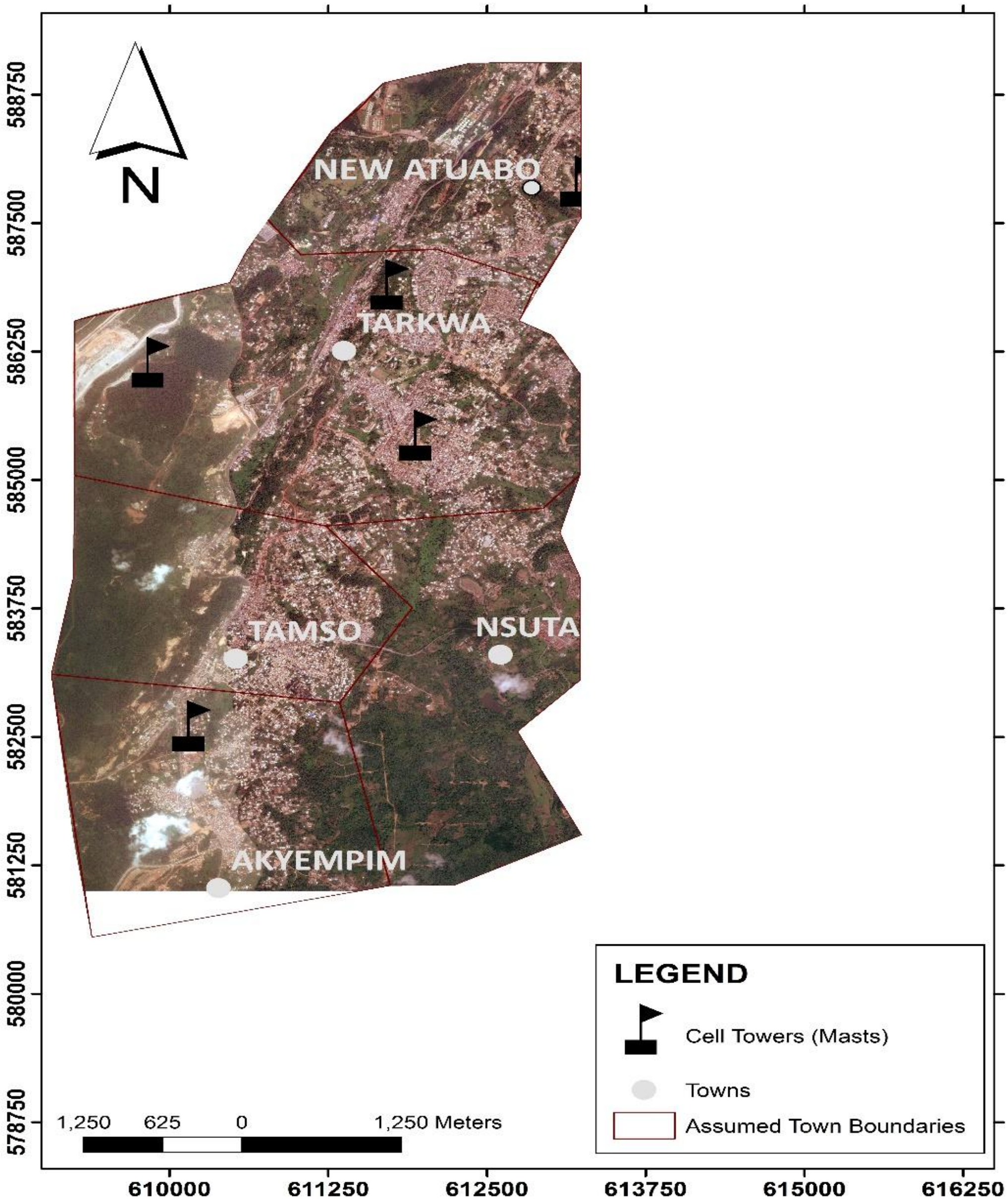

Fig. 2 Geo-reference Image of Study Area showing Assumed Town Boundaries

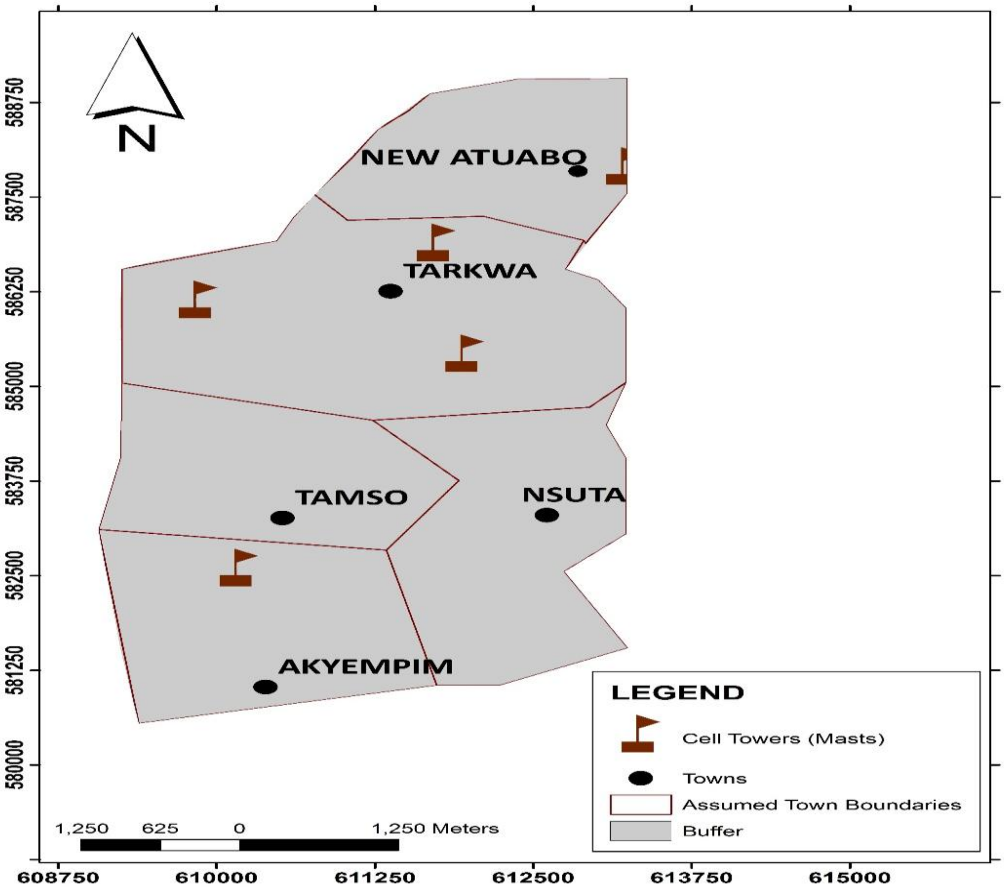

Fig. 3 Signal Coverage Buffer of the Study Area

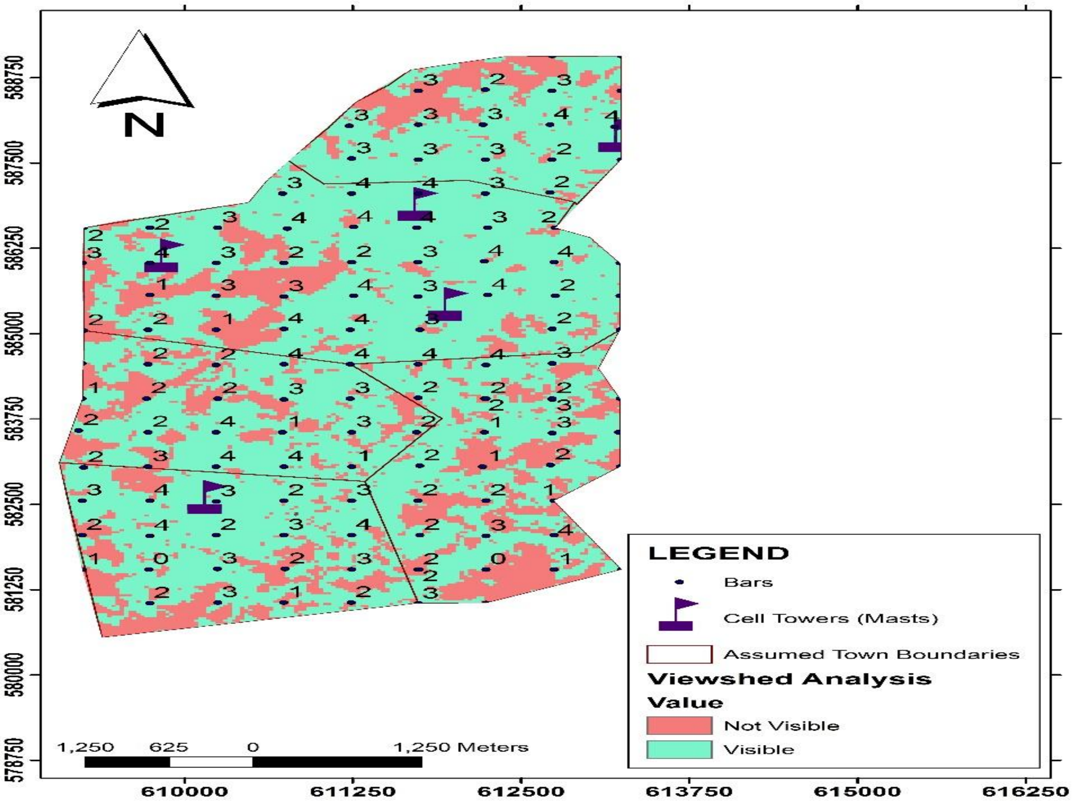

Fig. 4 Output of Viewshield Analysis

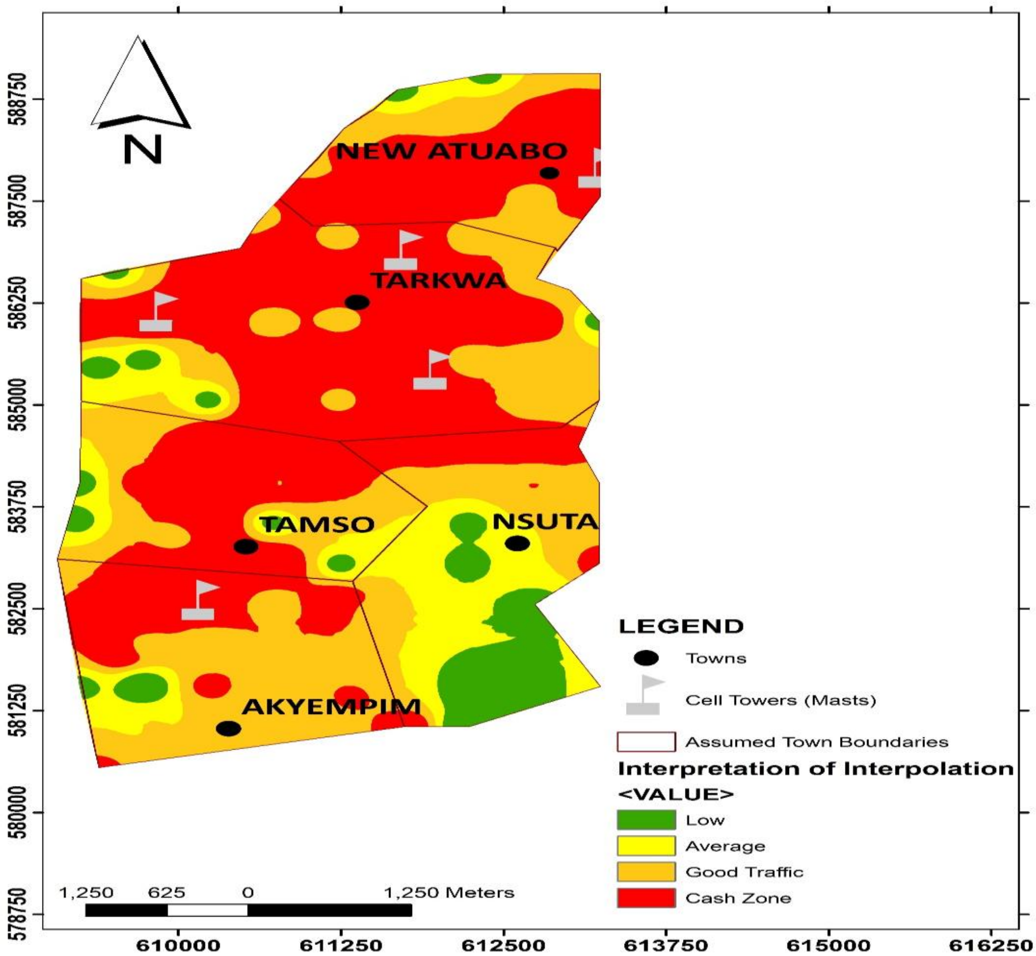

Fig. 5 Interpolated Signal Strength Map for the Study Area

Table 1 Classification of Strength Signal

BAR (S)	SIGNAL STRENGTH	TERM	COLOUR
1	Poor/None	Low	Green
2	Average	Average	Yellow
3	Good	Good Traffic	Orange
4	Very Good	Cash Zones	Red

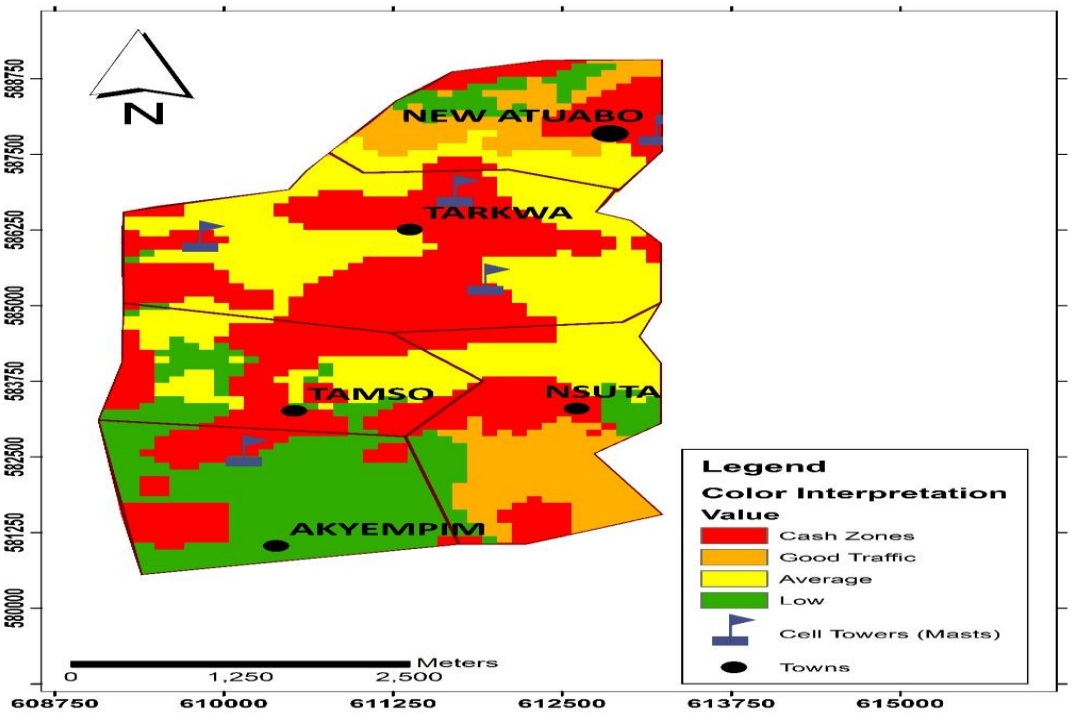

Fig 6 Signal strength map of the study area

3.2 Discussion

From Fig 2, four out of the five cell towers in the study area are spatially located along the portion with most built-up structures. Out of these four, three are in New Atuabo and Tarkwa where approximately 50% of the human settlement are found (see Fig 2). From the field data (see Fig 4), the cell tower located at Tarkwa closer to New Atuabo recorded the highest signal of 4 bar which reduces to 3 as one moves further from the mast radially. Similar trend was observed with respect to the mast at Akyempim and near Tamso. However, relatively lower signal values were obtained except for the periphery of the study area. Generally, measured signal strength values tend to be higher close to the cell towers but reduces further away from the cell towers. This suggests that, the nearer the mast is to a customer's location, the stronger the strength of signals received and vice versa.

The buffer produced (Fig 3) from the coverage distance of 62 km enclosed the entire study area, which suggests that the designed mast coverage area may be adequate, but the actual mast coverage may be less due to other factors. From Fig 4 and Table 1, results from the viewshed analysis showed that terrain elevation and physical objects such as buildings and trees affect the visibility of masts from reaching targeted areas. This is evident as most of the signal strength values between 3 and 4 bars fell within the visible regions of the final signal strength map whereas values from 0 to 2 bars appeared in the non-visible region (see Figs 4-6, and Table 1). Geographically, the visible region are the settlement areas within the built-up portion of the study area which have little terrain undulations with few high rising buildings. The non-visible areas are found at the fringes of the study area, particularly the northwest and the southeast parts. These sites are either undulating terrain with tall vegetation or mining sites (see Fig 2). Thus, terrain elevation, high rising buildings and tall vegetation are some geographic factors which cause poor visibility of signals in these areas.

The systematic sampling technique adopted and the result of IDW interpolation enabled a continuous data of signal strength values to be obtained, from which signal strength map was produced for the study area. From Fig 6 and Table 1, the cash zone (red band) was found within the settlement area where masts are located. For that reason, customers within this zone can enjoy good quality communication. Customers living within the settlement zone are more likely to patronize Tigo networks. This include resident of Tarkwa and some parts of Nsuta, Tamso and New Atuabo. Some residents of Tarkwa and some portion of New Atuabo experience very good signals. Some residents of Tamso experience good signals while other portions experience poor network signals due to obstruction by tall buildings. Some residents of Nsuta are likely to experience good quality signals while others have poor signals depending on the proximity of the mast to their locations. According to Fig 6, residence of Akyempim has the lowest signals thus the poorest quality of network. Some parts of the immediate surroundings of the mast have poor network signal, particularly the southern part. This condition may be due to a combination of other factors which hinders signals transmission such as vegetation and other environmental factors.

4 Conclusions and Recommendations

The study has successfully assessed telecommunication signal strength of Tigo in the study area. The spatial analyses revealed that generally, signal strength tends to be strong close to the cell towers but reduces further away from the cell towers. It was found that consideration of geographic factors such as visibility of cell mast, coverage area and obstruction by physical structure such as tall building influence the signal strength required for quality communication. It was also observed that although masts are supposed to supply signals to the entire study area, Akyempim and part of Nsuta and New Atuabo have relatively poor signal strengths. This was attributed to obstruction due to terrain undulations, high rising structure (buildings) and tall vegetation within the vicinity.

It is recommended that intermediate masts should be mounted in between the existing ones to enhance network communication in the low cash zone of the study area thus, Akyempim and some portions of Nsuta and New Atuabo.

Acknowledgements

The authors are grateful to the management of Millicom Ghana Limited for providing us with secondary data and relevant information needed to carry out this project. We are also indebted to the Geomatic Engineering Department for providing us with the resources and finally we say thank you to some of the final year students for helping in the field data collection.

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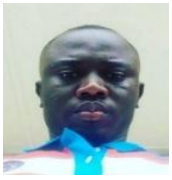

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