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Full Length Research Paper

Using geographic information system (GIS) to determine waste transfer stations in relation to location of landfill sites in Accra Metropolis

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The existing landfill sites in Accra are reaching full capacity and the acquisition of land for the construction of landfill sites has become very difficult due to rapid developmental activities in Accra. However, with the current rate of development which will cause the construction of landfill sites to be far from the source of generation, there is urgent need to get an intermediate facility, that is, waste transfer station where waste would be processed and compacted in long distance trucks to reduce the cost of waste transport and disposal. The objective of the study was to determine suitable places that could be used as waste transfer stations in relation to location of landfill sites using Geographic Information System (GIS). In this study, coordinates of all the container sites in Accra were determined with the Geographic Positioning System (GPS). The coordinates were then converted into points using ArcGIS and Microsoft Excel 2007 to help analysed the data collected. From the study, four transfer stations were located with the help of the GIS, namely: Ablekuman and Amomola (Transfer station 1),Oblogo and Weija (Transfer station 2),Ashongman and Agbogba (Transfer station 3), Ashaley Botwe and Ogbozdo (Transfer station 4).

Key words: Transfer, waste, landfill, station, geographical information system (GIS), geographical positioning system.

INTRODUCTION

In recent years, management of solid waste has become an issue of increasing environmental concerns of public debate (Rahman and Moten Ashraf, 2007). Historically, solid waste was collected in packer dump truck collection vehicles which delivered the waste directly to landfills. As landfills closed, haul distances became greater, giving rise to the use of transfer stations in which the waste is transferred to larger-capacity transfer trailers. The trailers are then hauled to the landfill site (US EPA, 1995).

The American Heritage Dictionary of English language defines waste transfer stations as a facility where solid waste materials, including yard waste, demolition materials, and household refuse, are transferred from small vehicles to large trucks for efficient transport to landfills, recycling centres and other disposal sites (AHDEL, 2011).

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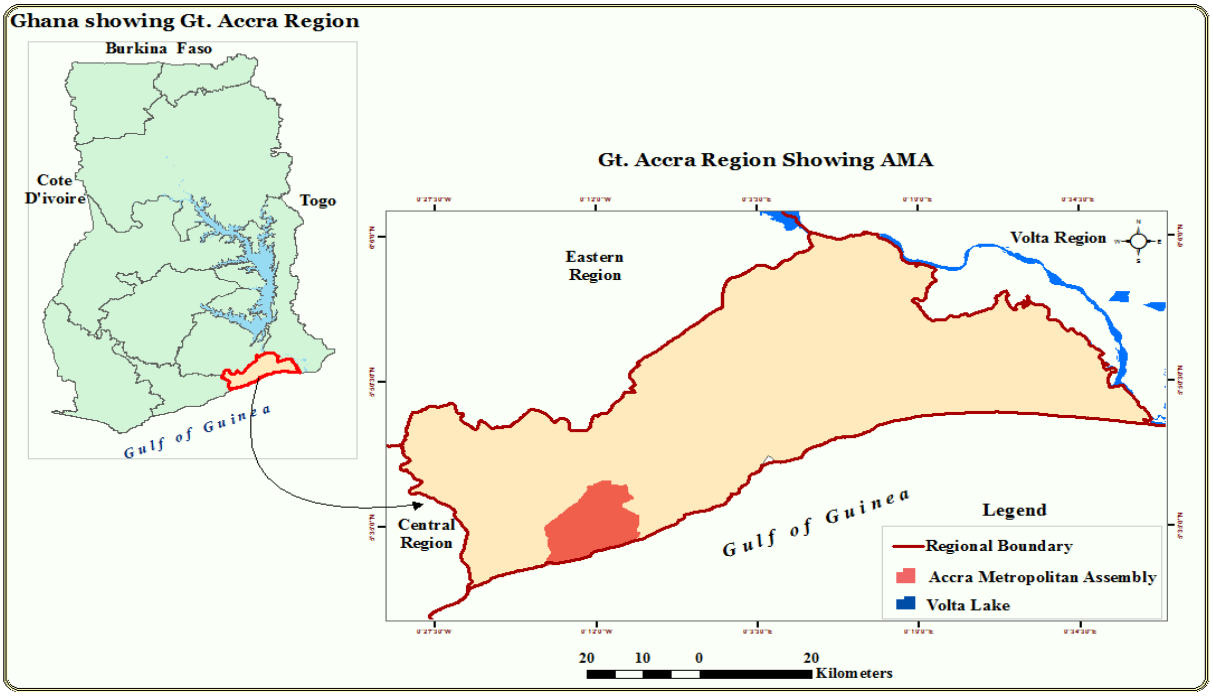


Figure 1. Map indicating the study area.

In recent years, transfer stations have also been used for diverting, collecting, and transporting recyclables as well as incorporating materials processing systems into the same facility (Zurbrugg, 2003). Transfer station currently being designed are typically enclosed in a building to reduce problems associated with noise, odour, and blowing litter and provide an aesthetically pleasing facility (Waste Transfer in Illiniois, 2001). Advantages As land becomes more urbanised, public resistance to new landfill sites increases. The current trend is to use network of transfer stations from which waste is transported to a remote landfill site, processing facility, or energy-recovery facility (Ojdemark, 2005). Transfer stations can be located on relatively small parcels of land and perceived by the public as more compatible with urban development than landfill sites. This challenge has resulted in final disposal sites being established far from the source of waste generation (Pieber, 2004). Hence, the need for waste transfer stations which can serve as an intermediate between the sources of generation and the final disposal sites. When this is established it will then ensure effective collection of waste from the city, because haulage distance will be reduced and the rate of waste collection by the trucks will increase (Bilitewski et al, 1994). Furthermore, the cost of collection, fuel and maintenance will reduce. Also, haulage distance would be reduced; thereby reduction in emission into the atmosphere by these trucks (Böhmar, 1995).

To maximize waste collection efficiency, transfer stations should be located centrally to waste collection routes. As a rule of thumb in urban and suburban areas, transfer stations should be no more than 10 miles away from the end of all collection routes (Pieber, 2004).

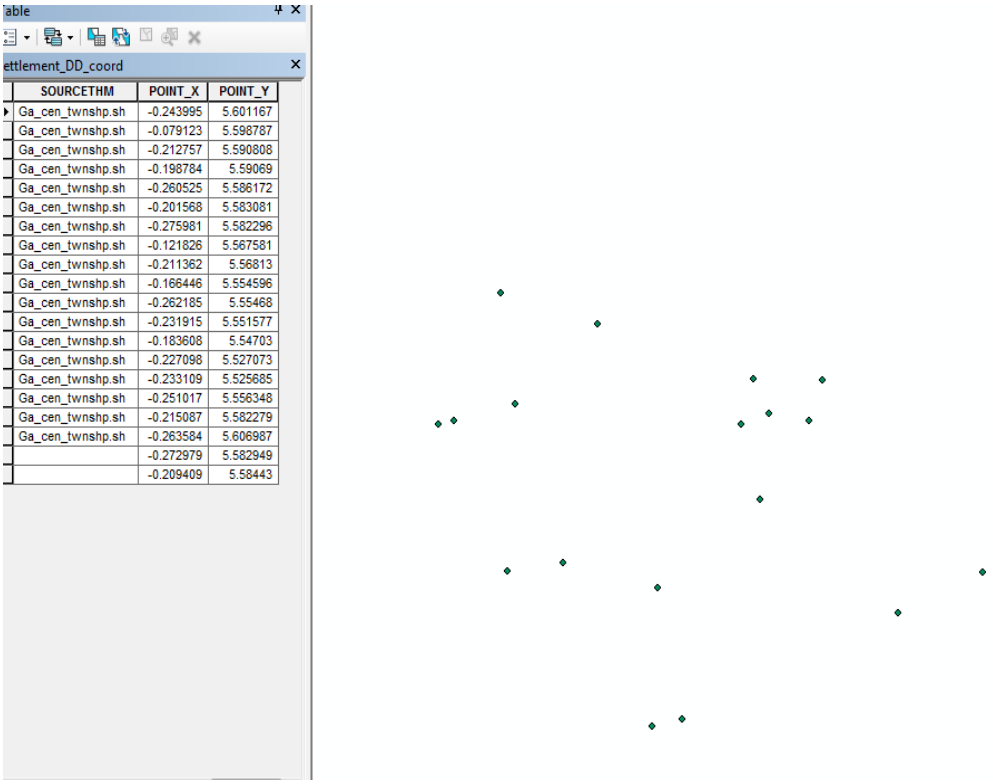
The fast urbanization of the city of Accra has made finding a piece of land to be used as landfill site very challenging. There is greater demand of land for real estate development in Accra. These estates frown against landfills in their neighborhoods.

The estate developers take large land areas and their presence then become a great challenge in locating a landfill. The challenge of not being able to acquire land close to the generation points, affect waste collection. This occurs because of the estate developers acquiring large land areas; hence, landfills must be built further from the generation points. The problem this study sought to address is to identify suitable places that can be used as transfer stations in relations to the location of final disposal sites in Accra using Geographic Information System (GIS).

This research used GIS to identify possible locations that could be used for transfer station, considering all the factors needed to establish such a facility.

MATERIALS AND METHODS

Accra is the capital city of Ghana and also the regional capital of the Greater Accra Region. It is Ghana's primate city, serving as the nation's economic and administrative hub. It is furthermore a centre of culture and tourism, sporting a wide range of nightclubs, restaurants and hotels. Accra stretches along the Ghanaian Atlantic Coast, bounded to the east by the Ga East Municipal Assembly, to the west by the Ga West Municipal Assembly and to the South by the Ga South Municipal Assembly. Most of the people in Accra are



SOURCETHM	POINT_X	POINT_Y
Ga_cen_twnshp.sh	-0.243995	5.601167
Ga_cen_twnshp.sh	-0.079123	5.598787
Ga_cen_twnshp.sh	-0.212757	5.590808
Ga_cen_twnshp.sh	-0.198784	5.59069
Ga_cen_twnshp.sh	-0.260525	5.586172
Ga_cen_twnshp.sh	-0.201568	5.583081
Ga_cen_twnshp.sh	-0.275981	5.582296
Ga_cen_twnshp.sh	-0.121826	5.567581
Ga_cen_twnshp.sh	-0.211362	5.56813
Ga_cen_twnshp.sh	-0.166446	5.554596
Ga_cen_twnshp.sh	-0.262185	5.55468
Ga_cen_twnshp.sh	-0.231915	5.551577
Ga_cen_twnshp.sh	-0.183608	5.54703
Ga_cen_twnshp.sh	-0.227098	5.527073
Ga_cen_twnshp.sh	-0.233109	5.525685
Ga_cen_twnshp.sh	-0.251017	5.556348
Ga_cen_twnshp.sh	-0.215087	5.582279
Ga_cen_twnshp.sh	-0.263584	5.606987
	-0.272979	5.582949
	-0.209409	5.58443

Figure 2. Points generated from the coordinates.

office workers, factory workers, Artisans and traders (Ghana Web, 2010). The study was conducted in the Accra Metropolitan Assembly which is made up of eleven sub-metros, namely: Ablekum Central, Ablekum North, Ablekuma South, Ashiedu-Keteke, Ayawaso Central, Ayawaso East, Ayawaso West–Wuogon, La, Okaikoi North, Okaikoi South, and Osu Klottey (Ghana Districts, 2006) (Figure 1).

Data collection

Geographical position System (GPS) was used to get the coordinate of all the container sites in the Accra Metropolis.

This involved taking the coordinates of all the waste container sites in Accra and also the final disposal sites. Furthermore, data on the traffic situation, population density, land use, natural condition (vegetation, water bodies, etc.) and human settlement will be obtained from the appropriate agencies.

The coordinates of the various places designated to be used as final disposal sites, namely: New Bortianor and Adjen-Kotoku were also taken by using the GPS and the coordinates of the current dump sites were also taken.

Analysis of data

These coordinates were then converted into points, using ArcGIS and Microsoft Excel 2007 to analyse the data collected.

The coordinates were converted into degree decimals, by dividing the minutes by 60 and dividing the seconds by 3600 e.g. 5° 33´ 30´´ becomes 5.55833 and the figures typed in Excel.

The excel table was opened in ArcGIS as a dbf file and exported as shape file which was displayed as points in ArcGIS as shown in Figure 2.The Sub-Metro boundary was obtained from Accra Metropolitan Assembly and using ArcGIS software the various buffers (3, 6, and 9 km) were created from the external boundary of the merged sub-metro as shown in Figure3. The average distances amongst the various container sites were determined with the help of the GIS.

Also, the average distance between these container sites and the final disposal sites were also determined to help determine the possible places that could be used as waste transfer stations.

During the analyses, the following were considered to help determine those suitable places that could be used as transfer stations: closeness to water body and settlement, accessibility, closeness to school, health facility, closeness to source of drinking water, and traffic situation within the study area condition of roads, e.g. first class, second class and possible shortest distances to the final disposal sites. To establish the aforementioned factors in the analysis, digitized data of all the mentioned layers were obtained from Centre for Remote Sensing and Geographic Information System (CERGIS)-Legon, and Ghana Statistical Services and Survey Department.

All the various datasets were converted into same projection, to facilitate super imposing one on the other, for the purpose of analysis (Figure 4).

RESULTS AND DISCUSSION

In using the ARCGIS software, the various distances along roads to final disposal, transfer stations sites were generated.

There were 101 communal container sites identified during the time the coordinates were taken in the whole

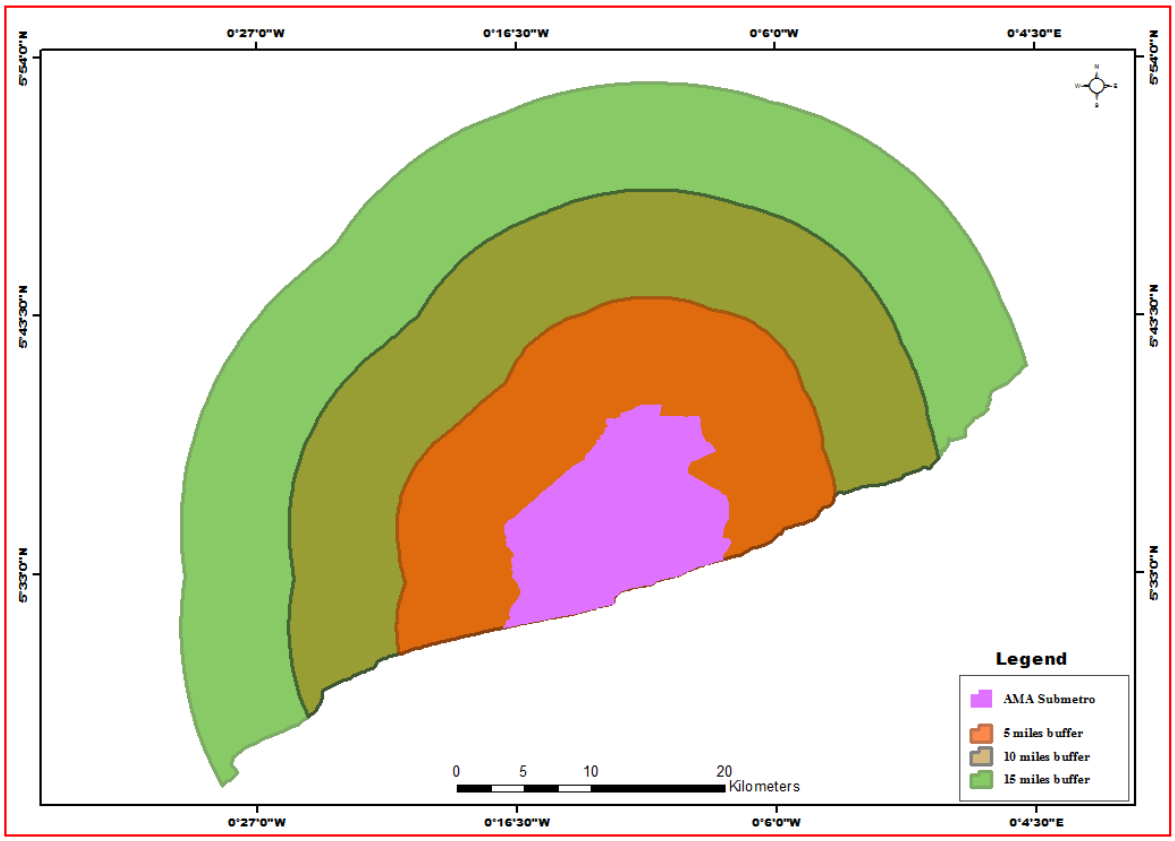


Figure 3. The 5, 10 and 15 miles buffer created from the external merged boundary of the sub-metro.

Accra Metropolis. These communal containers are placed to support the management of solid waste generated in the communities. Through the survey work, it was realised that these containers are placed to serve mainly the markets, communities, and institutions upon request. However, the household are supposed to register with private waste companies to collect their bins on an agreed day and at a fee.

Waste transfer stations are usually established to ensure effective collection and also help in reducing the cost of operations. It is generally less expensive to deliver collected Municipal Solid Waste (MSW) to transfer stations where it can be consolidated into large loads that can be transported by trailer trucks, rail cars, or barges to large-scale management facilities than transporting the same amount of MSW in substantially smaller vehicles. The latter increases fuel consumption and number of trips needed to transfer waste to final disposal sites. To establish the construction of waste transfer station, distance is very important. In view of this, the sub-metro boundary obtained from the AMA with the help of ArcGIS software, various buffers (3, 6, and 9 km) were created from the external boundary of the merged sub-metro as shown in Figure 3. These were done to inform decision or policy makers as to the acceptance of the concept of waste transfer stations. Technically, it has been established that ideally transfer stations are considered when the source of waste generation is 6 km from the final disposal site, which then makes it economically more viable (US EPA, 1995).

However, from the categorisation made on the maps, it was realised that most of the current dumping sites are within the 6 km range except the compost and recycle plant being constructed by Zoomlion Ghana Ltd. at Adjei Kotoku which was beyond 6 km. But most of the dump sites currently being used are full and looking at the rate at which Accra is developing, there is greater tendency that landfill or dump sites to be acquired will go beyond the 6 km. This information then prompts the need to consider waste transfer station concept to enable solid waste to be managed effectively.

In the location of the various transfer stations depended on the necessary factors used to selected a suitable place for the establishment of a waste facility. In this research, maps of all these information were collected and super imposed on the map of Accra to get the maps in Figures 5 and 6.

From Figure 5 as shown in the map, four suitable waste transfer stations were located with the help of the GIS. These transfer stations from the map were located around: (a) Ablekuman and Amomola (Transfer station 1); (b) Oblogo and Weija (Transfer station 2); (c) Ashongman

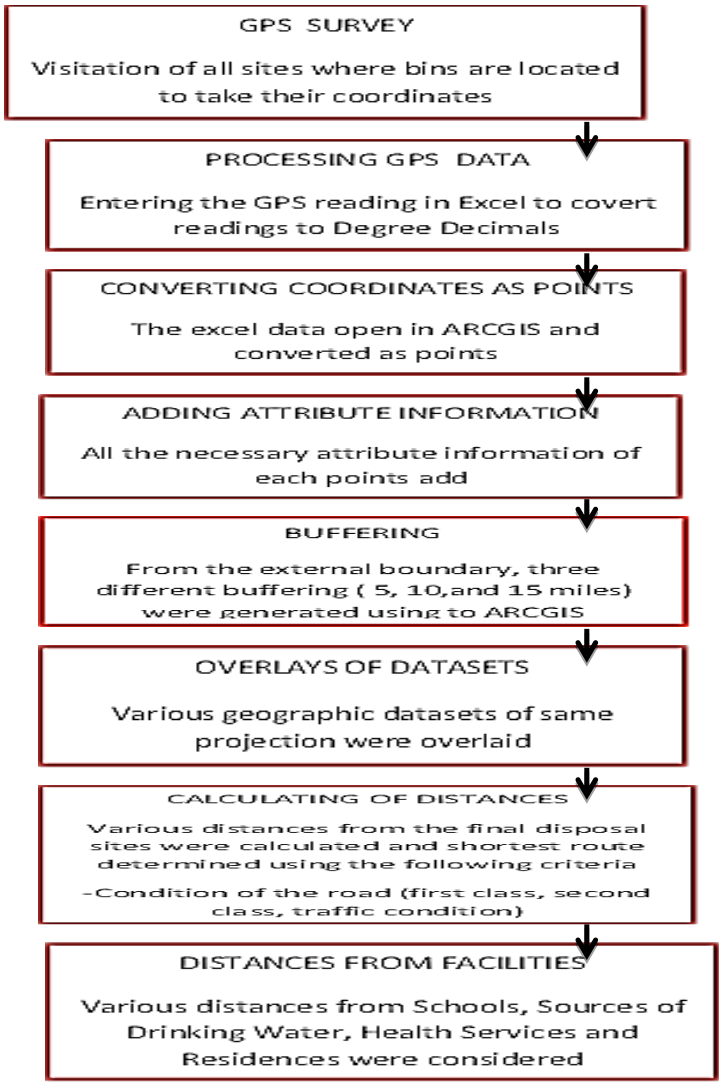


Figure 4. Flow chart of the methodology.

and Agbogba (Transfer station 3); (d) Ashaley Botwe and Ogbodzo (Transfer station 4). These four places where identified with the assistance of the GIS, which through queries in relations to the information fed in relations to the necessary factors for the establishment of suitable place for a waste facility, namely: nature of vegetation, closeness to water body, closeness to settlement, and traffic condition. It was identified that averagely all these places identified met the criteria for the establishment of a waste facility, when the query was carried out through the GIS. This can be identified through the maps in Figures 5 and 6.

Assessing the location of the various proposed transfer stations identified with the help of the GIS, they are all placed at vantage points. The establishment of these transfer stations at the proposed locations will go a long way to help salvage some of the challenges we have in the collection and transportation of solid waste in the capital city.

The average distance that a truck needs to travel between all the sub-metro to the final disposal sites in relation to traffic condition ranges between 22 and 37 km and the average distance a truck needs to travel to a nearby transfer station in relations to traffic condition ranges between 6and15km from Table 1. This then shows a drastic reduction in distance that a truck has to travel to dispose waste, because the truck needs not to travel between 22 and 37 km to dispose waste, but rather 6and 15km.

Also, it could be observed from the map shown in Figure5 that all the transfer stations are located outside the jurisdiction of the Accra Metropolitan Assembly, which then place the establishment of these transfer stations in an advantageous position, because most of these places are not so much developed. Furthermore, the establishment of these transfer stations in these areas

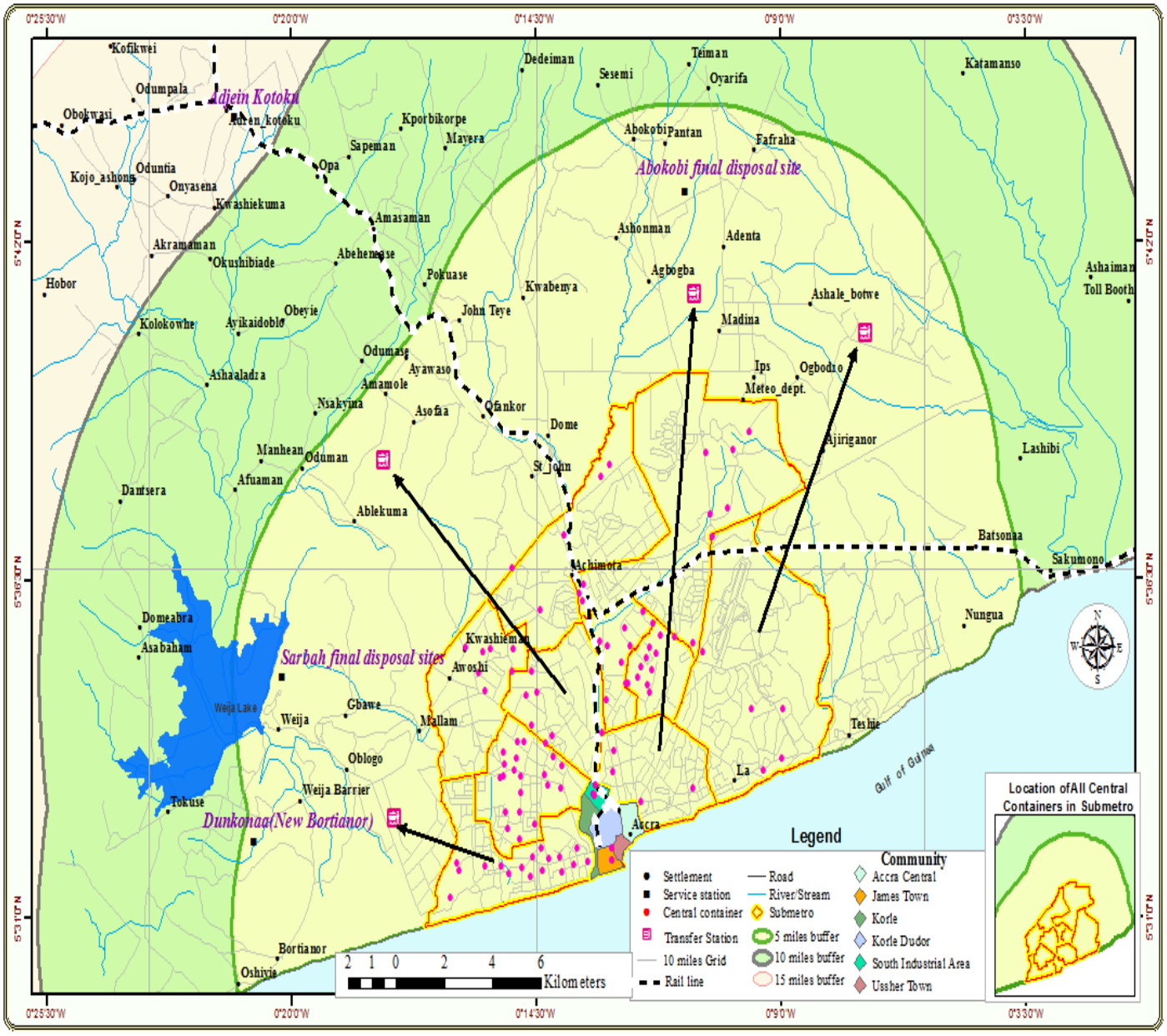


Figure 5. The arrows in the map indicate location of all container sites in the sub-metros and location of transfer stations.

would hasten the development and thereby improve economic activities.

From Table 1, La sub-metro has the longest average distance in relations to traffic condition to the final disposal site, whiles Okaikoi North has the shortest average distance in relations to traffic condition to the final disposal sites. This could be due to the location of the sub-metro and also the distances of the location of container sites within the sub-metros.

The identified waste transfer stations were all within the 3 km buffer which implies that their establishment would help solve the challenge with the rate of waste collection due to distance landfills.

Conclusion

The GIS was used to identify four waste transfer stations of which from the analysis it can serve all the various container sites in the AMA and even other Municipal and Districts Assemblies.

The coordinates of the entire communal container sites in the AMA which are known through the work, could help the assembly in monitoring of location of communal container sites and also how to effectively allocate communal containers.

The four suitable waste transfer stations identified are all outside the jurisdiction of the AMA. This then indicates

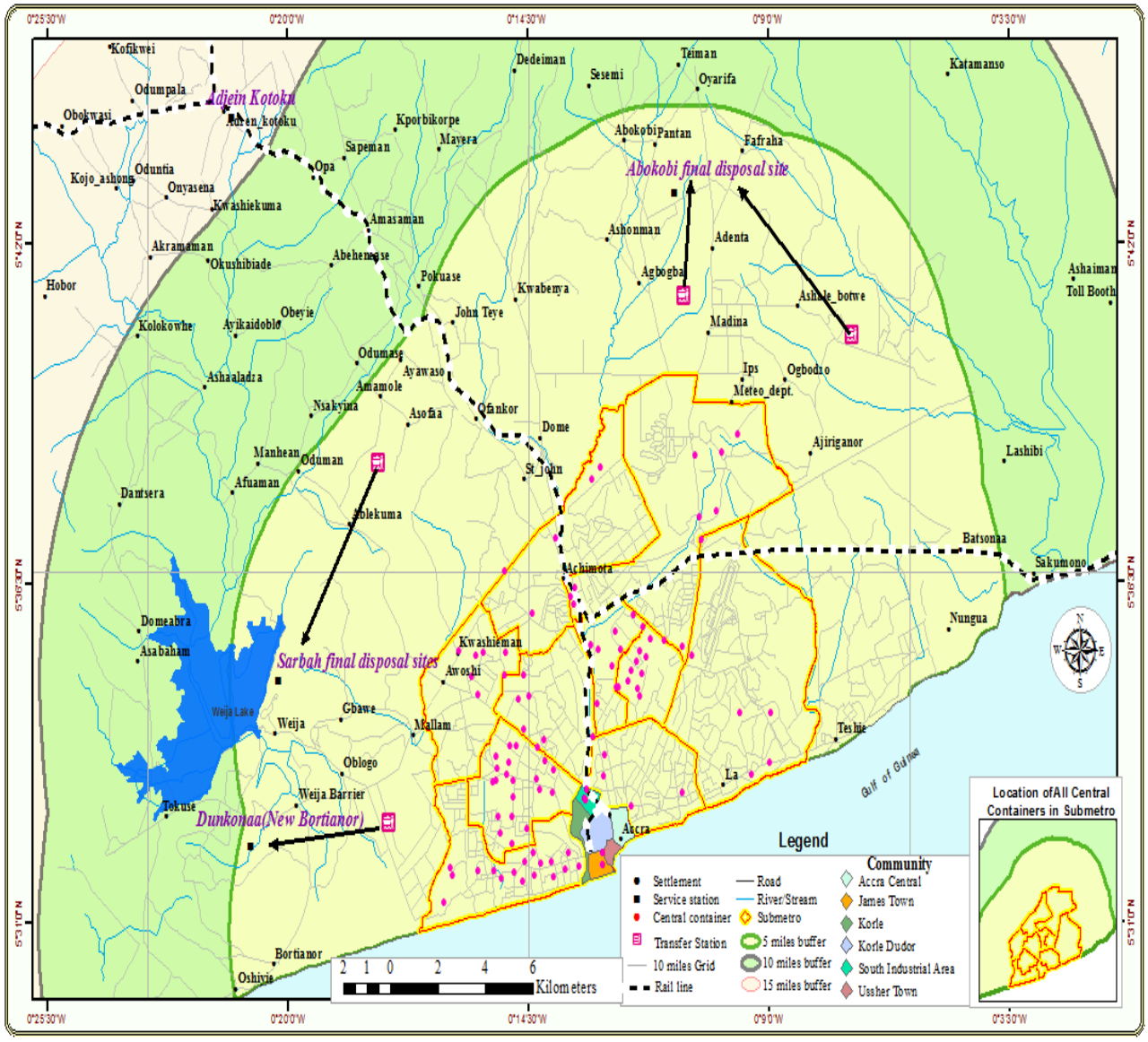


Figure 6. The arrows in the map indicate locations of transfer stations and landfill sites.

Table 1. The average distances to final disposal site, nearby transfer Stations, and transfer stations to final disposal site.

Sub-metro	Average distance to final disposal site	Average distance to nearby transfer station	Average distance from transfer station to final disposal Site
Ablekuma North	28	8	20
Ablekuma South	33	8	25
Ablekuma Central	31	6	25
AshieduKeteke	36	10	26
Ayawaso Central	26	13	13
Ayawaso East	28	15	13
Ayawaso West	29	7	22
La	37	13	24
Okaikoi North	22	11	11
Okaikoi South	32	11	21
OsuKlottey	32	16	16

indicates that, there is urgent need to establish waste transfer stations in the identified places to avoid development catching up with these areas.

It could be concluded from the analysis that fuel consumption would reduce, because the distance to travel will be reduced, because final disposal of waste will be done by large capacity trucks or trailers.

Conflict of interests

The author did not declare any conflict of interest.

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