3-1 Introduction

One of the important criteria to make right decision in selection of landfill site is site area requirements. For this purpose, Municipal Solid Waste (MSW) volume need to be disposed into this site should be estimated, in addition to consideration of the reduction in waste volume when proper solid waste management is achieved.

3-2 Characteristics of Study Area

Khartoum state covers an area of about 22,142 km^2 [**https://en.wikipedia.org**]. It is divided into seven localities { Karari , Ombaddaa, Omdurman, Bahri, Shareq- Alneel, AL Khartoum, Jabalawliya}, located in the heart of Sudan at the confluence of the White Nile and the Blue Nile, where the two rivers unite to form the River Nile, bordered from the northeast side by River Nile State and from the North West side by the Northern State and from the eastern and south-eastern side by the Kassala, Gedaref and Gazera states. The state lies between longitudes 31.5 to 34 °E and latitudes 15 to 16 °N.

The northern region of the state is mostly deserting because it receives barely any rainfall, whereas the other regions have semi-desert climates. The weather is rainy in the summer, and cold and dry in the winter. Average rainfall reaches 100–200 mm in the north-eastern areas and 200–300 mm in the northwestern areas.

The temperature in summer ranges from 25 to 40 °C from April to June, and from 20 to 35 °C in the months of July to October. In winter, the temperature declines gradually from 25 to 15 °C between March and November.

The total population of Khartoum state at 2008 was recorded as being 5,274,321 with the rural population of Khartoum state being 1,001,593 according to 5th Sudan population and housing census-2008 , and it estimate the total population from year 2009 to 2018 in Khartoum state as shown in table (3-1):

Table (3-1): Population estimates for the years (2009-2018)

[Central Bureau of Statistics, 2008]

Year	Total population (million)
2009	5.5
2010	5.8
2011	6.0
2012	6.3
2013	6.5
2014	6.8
2015	7.1
2016	7.4
2017	7.7
2018	8.0

Based on above situation, a large amount of MSW could be generated each year, which need study to estimate waste volume disposal into landfill and proposed proper landfill sites selecting with lesser environmental impact.

3-3 City Survey

The state of Khartoum is divided into seven localities { Karari , Ombaddaa, Omdurman, Bahri, Shareq- Alneel, Alkhartoum, Jabalawliya} . These seven localities are further subdivided into many neighborhoods. As a part of this study, digital map of Khartoum state are prepared by implementation of Geographic Information System (GIS) to show layers of: urbanized area, industrial area, trade centers, hospitals, main roads, stream and channels, airports, gardens, agriculture lands, forest, transfer stations. Resources of collected data obtained from visual survey, LANDSAT satellite of resolution 15 m taken at 2010 and Google Earth, Central Bureau of Statistics, Supervisory Board of cleanliness in Khartoum State, Mearage Company. Al Khartoum state map and Al Khartoum with its locality produced is shown in fig (3-1).

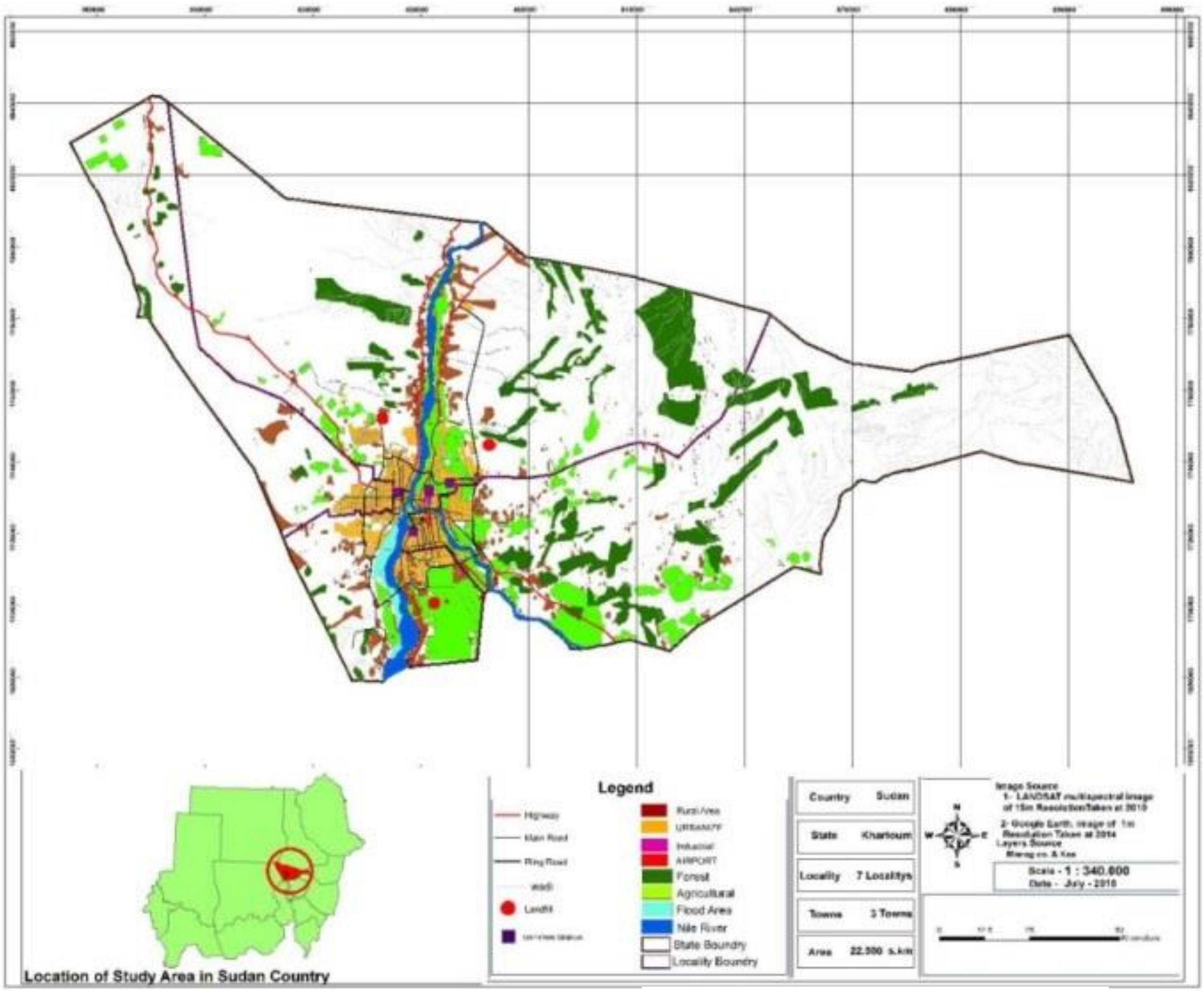

Figure (3-1): Location of study area

3-4 GIS Implementation for Landfill Site

Different methods of site selection for waste disposal have been developed over the last decades to provide more efficient waste disposal allocation.

Conventional location models for solid waste management in the late l960s focused on financial optimism [**Leao, S., Bishop, I., and Evans, D., 2003**] which includes the operation costs of the facility, the costs of the transportation of waste to the facility and the revenues generated by the facility such as energy.

During the 1980s and 1990s, people became aware of the potential of pollution due to waste disposal which led to more restrictive environmental regulations and to increase the emphasis given to the recycling and waste reduction [**Leao, S., Bishop, I., and Evans, D., 2003**]. One ofthe preliminary researches on this approach is cited as lane and McDonald (1983) and they had considered only environmental properties of the sites on a map layer based approach, Whereas DRASTIC and LeGrand methods evaluated the sites by focusing only on a single parameter which is for example groundwater potential [**Noble, l992**].

As the landfill site selection process depends on a variety of laws.Regulations and factors, large volume of spatial data should be evaluated and processed. To overcome this difficulty, GIS is commonly used to select suitable sites for landfill [**Baban, S., Flannagan, J., 1998; Allen A. R., 2002**].

For general GIS, although it is very useful in siting experiences, lacks the ability to locate an optimal site when compactness and other factors are consideredat the same time. For this purpose, a mixed integer programming model was developed to obtain a site with optimal compactness by [**Kao, J.J,. and Lin, H., 1996**] and extended to include multiple siting factors. However, because the computational time with a conventional mixed integer programming package for solving the modelis time consuming and impractical, a raster based C program for landfill siting with optimal compactness was developed [**Kao, J.J,. and Lin, H., 1996**].

A multi objective optimization model is developed to determine the efficient aggregation of land parcels to use as a solid or hazardous waste landfill by [**Minor, S.D., and Jacobs, T, L., 1994**]. A constraint which measures compactness and contiguity as a function ofthe outside perimeter and area of the subregion is introduced in this model which optimally selects and sizes the landfill site and considers land purchase cost, compactness and contiguity.

A network geographic information system (GIS) was developed to improve the effectiveness of a complex municipal solid waste landfill siting procedure and make siting related information available to the general public [**Kao, J.J., and Lin, H., 1996**].

Because of the complexity and dependency of different decision groups,design of solid waste management systems requires consideration of multiple alternative solution and different criteria. Multi criteria Decision Analysis (MCDA) approach is commonly used to solve the landfill site selection problem and provide decision makers the most satisfactory and preferable alternative. In the study done by [**Chang, S., and Chan C. W., and Huang, G.H., 2003**] simple Weighted Addition method, Weighted Product method, TOPSIS (Technique for Order Preference by Similarity to the Ideal solution). Cooperative Game Theory and ELECTRE methods of MCDA were used and compared to get the most preferable solution of solid waste management.

To overcome the weakness of different multi objective programming models which is the ignorance of qualitative and subjective considerations such as environmental and socio-economic factors an integrated multi criteria decision analysis and in exact mixed integer linear programming approach for solid waste managementwas developed and the five MCDA methods which were used in the previous study of authors were adopted to evaluate the landfill site alternatives(**Chang, S., and Chan C. W., and Huang, G.H., 2003**].

[**Siddiqui, M.Z., and Everett, J.W., and Vieux, B.E., 1996**] developed a methodology to find best locations for landfills by integrating GIS and Analytical Hierarchy Process (AHP) which is called spatial-AHP. The evaluation of the land suitability was based on the environmental characteristics of the site and proximity to the populations.

A GIS based weighted linear combination (WLC) is created for selecting suitable sites for animal waste using a raster GIS. The selected factors affecting the suitability of the site are weighted using the Analytical Hierarchy Process (AHP) which employed and objectives oriented comparison technique to formulate the pairwise comparison matrix [**Basnet, B.B., and Apan A. A., and Raine, S., R., 2001**].

3-5 MSW Composition

There are three transfer stations currently in Khartoum state as shown below:

1. Teba transfer station, which is located in Khartoum locality, serve waste collected from Khartoum and JabalAwlya localities.
2. Abo Weledat transfer station, which is located in Omdurman locality, serve waste collected from Um Badah, Omdurman and Karary localities.
3. Hattab transfer station, which is located in Bahari locality, serve waste collected from Khartoum Bahari and ShargElneel localities, see figure (3-2).

Figure (3-2), Hattab Transfer station located in Khartoum state

The transfer stations are basic small open area facilities where waste collection vehicles discharge their load on the ground. Waste is then loaded onto larger trucks and taken to the dump sites. No long-term storage of waste occurs at a transfer station: waste is quickly consolidated and loaded into a larger vehicle and moved off site. Usually in a matter of hours. The operation of the transfer is expected to be outsourced until the required trailers and trucks are available for the Mayoralty to operate them [**Tecobanoglous, G., and Kreith, F., 2002**].

Table (3-2) shows the adopted Municipal Solid Waste Composition of these transfer stations in Khartoum state, figure (3-3).

Table (3-2): Khartoum state MSW Composition[Abo baker H.A. 2013]

Waste Constituent	Percentage by Weight
Organic	49.5%
Paper	11.8%
Plastic	12.7%
Glass	3.5%
Metals	1.7%
Others	20.8%

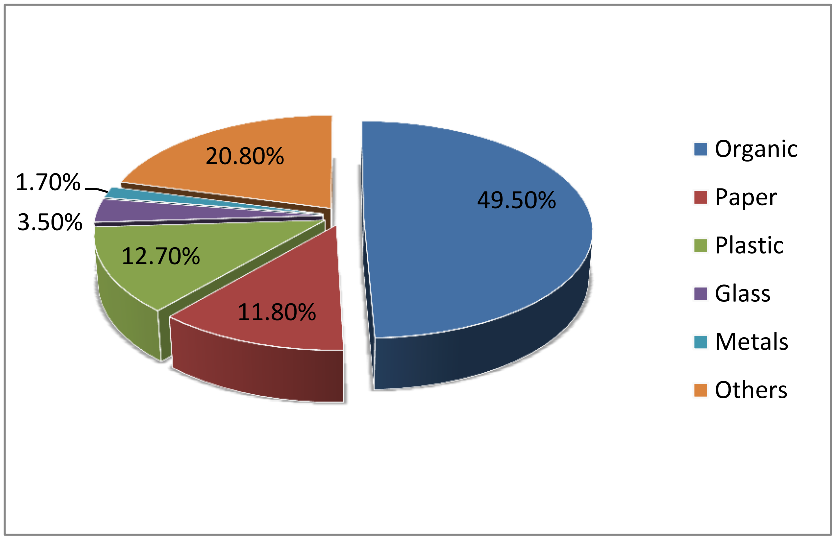

Figure (3-3): Khartoum state MSW Composition Percentage, 2013

3-6 Estimation of Khartoum State Population:

The population of Khartoum state is a key element in the assessment of the quantities of solid waste generated. One method for estimating the total amount of solid waste generated is to rely on published data for countries with similar socioeconomic indicators to obtain the amount of waste per capita per day. This number multiplied by the population being studied can provide the total amount of solid waste generated.

3-6-1 Population Growth

The total population of Khartoum state studied at year 2008 by Central Bureau of Statistics which mentioned earlier in table (3-3), the population growth in any society usually is affected by two factors, one is the net growth between birth rates and death rates , the other is the base of net migration ,the second rate is the difference between the number moving in and moving out, between rural and urban center and this is directly related to economic indicators and employment opportunities in the city when compared with employment opportunities in rural centers **[ISI, 2003]** The first population census conducted In 1955-56 showed that the total population in Sudan was 10.1 million persons, in 1973, it was 14.1 million, in 1983 it was20.6 million persons while it reached 24.9 million persons in 1993 then, it increased to 39.2 million persons in 2008, with a growth rate of 2.7% in the period 1993-2008.

The information available in the 2008 census in the country permits the analysis of life – time internal migration from the data. It was observed that internal migration has continued its upward trend since 1973 Census. The volume of migration had increased from 0.7 million of person in 1973 to 1.3

million person in 1983 and 3.4million person in 1993. This upwards trend of internal migration has continued showing that the number who had changed residence has reached 3.7 Million in 2008 which represent about 10% of the total population enumerated in the 2008 census.

Probably due to civil war which lasted for more than 20 years. Migration seems to have gained further momentum since 1973 census. In addition to this push factor increased migration is facilitated by easy and modern means of transport, increased awareness resulting from literacy and education, job opportunity in urban centers as well as in more developed and naturally endowed areas of the country also have played an important role in stimulating population movement (pull factor).

Table (3-3): Population of Khartoum state by Locality and percentage of total population in 2008

Locality	population 2008	Percent of Total population
Karari	714,079	14%
Ombaddaa	988,163	19%
Omdurman	513,088	10%
Bahri	608,817	11%
Shareq -Alneel	868,147	16%
Alkhartoum	639,598	12%
Jabalawliya	942,429	18%
Total	**5,274,321**	**100%**

Table (3-4), Population Projection for period of the ELOT [CBS]

Year	Population
2014	6.809.046
2015	7.095.148
2016	7.385.158
2017	7.687.547
2018	7.993.851

3-7 Gathering Criteria Data and Prepare Geographic Database

The collection and build a geographical database of more stages that require accuracy in the labor process and the cost of material and dedication in the effort, in addition to the long time it takes for this process. it's done preparation and processing model database after the preparation of the list of requirements and criteria mentioned above ; so that the database with the conditions and criteria that have been formulated and processed in line , we have obtain on the available data from different ministries and institutions . Some of these data were in the form of shape file , others were in the form of optically scanned maps , and thus has been the introduction of this data to the GIS program , review and audit its coordinates and correct some of the distortions it, then do a numbering maps scanned . Database consisted of two main types, as it follows:

3-7-1 Spatial Data

Also known as *geospatial data* or *geographic information* it is the data or information that identifies the geographic location of features and boundaries on Earth, such as natural or constructed features, oceans, and more. Spatial data is usually stored as coordinates and topology, and is data that can be mapped. Spatial data is often accessed, manipulated or analyzed through Geographic Information Systems (GIS), divided in to:

1. **Points**: it was used to represent the phenomena that can be ignored dimensions, such as ground water wells, eyes and springs, waste generation centers in the communities.

2. **Lines**: it was used to represent the longitudinal extension of the phenomena, which can be ignored thickness compared to the length such as, road network, and the valleys.
3. **Polygons**: it was used to represent the phenomena which have dimensions and spaces, such as, Land uses, built area, soil, and groundwater basins and climate data and others.

3-7-2 Attribute Data

It is also called non- spatial data, which is either the amount of digital information (Quantitative) or non- quantitative information (Qualitative) such as names and addresses. This data is important for the map in order to clarify the spatial data; every map need describe data to prepare in the tables to represent spatial data on maps.

The Model database includes (7) layers, 3 of them are in the form of polygon, the other 3 layers are in the form of line and the remaining one is in the raster system. All these forms of the basic database will be used in the analysis and access to achieve the final outcome of the process.

3-8 Rating Scale Data (Common Scale)

This measure is designed to determine the degree of relevance of each class of maps parameters of evaluation criteria categories suitability of the land for the process of landfill sites planning, and re simplify the values stored within network (Grid Theme) to facilitate the deal with them within the spatial analysis environment for GIS programming and convert the value and text input to digital input.

There are many kinds for Gauges of data classification, It is followed this common measure to determine the relevance of each category in each layer to assess the suitability of the land relative, and this measure is based on the values of (1-10), where the value of 10 is considered the highest degree of appropriateness for the project, while a value of 1 is considered the lowest appropriate degree in the planning process

3-9 Processing Standards using Spatial Analysis Function

The methodology followed in the best landfill sites on some of the methods of analysis Planning Spatial and statistical data analysis and processing, which owns GIS could be held objectively by using 9.3 Arc GIS which was used in this study.

Since this study data came in two main types: : linear pattern and style networking , it is necessary to clarify the place of how to carry out the analysis , as appropriate to each style of these two types.

a- Rasterization:

Modeling operations make it easier to deal with the data in a Raster form, so all the maps have been converted from Vector to Raster.

The process of modeling is only a generalization of the characteristics of the phenomena in order to determine its behavior, and the way cells in the data storage in the Raster form is also generalization of the recipes phenomena.

b- Reclassification:

This steps is useful in rearrange and distributed the cells ; making it easier to deal with them, in addition to being used as a criterion in the model, and therefore it is classified into categories standards , and are given the most appropriate cells rank 10 , and the least appropriate rank 1 according to common scale , to result in re-classify for each criterion new layer are automatically added to the interface of the program.

c- Weighted Overlay:

GIS plays a great role in the planning and determining the best landfill sites due to its universal advantages and the ability to link all the factors and variables with each other in determining the best locations that vary in their nature according to the economic, social, geological, geomorphological and environmental criteria, as well as the climatic and public acceptance criteria.

This study focuses on weights analysis and collection with a view to aligning them with the higher standards to achieve accurate results according to the trends adopted by the researcher; through weakening the role of the criteria that could pose a threat to the environment and humans and go in line with such criteria and circumstances which are of less negative impact or have no negative impact at all.

Therefore, GIS has provided the flexibility to trade-off variables and give one of the criteria affecting more weight than the rest of the standards and the percentage , and this point of the study have resorted to the use of weighted values to give actors in the success of the best locations and the greater weight of the other elements , were numerous GIS tools to calculate the impact of the weights of the criteria , it is these many Weighted Overlay function falling under the list of Spatial Analyst tools which enables the user to insert the weights of the criteria provided that the total sum of the weights is equal to 100%[**الرحيلي، عهود عائض ، 2010**].

d- Buffer:

Measures the campus spatial scale or scope of service to influence a certain milestone on the surface of the surrounding area to build a certain distance is entered him based on planning standards; for these distances are excluded from the analysis and modeling processes [2012 ، صهيب ، ابو حبايب]. so do not fall milestones which we plan to her and the transfer of waste dumps within this buffer zone, but the areas of the planning process, including the exclusion .