4-7 GIS Implementation

Map of Khartoum state and its localities collected from Mearage Company and digitize it from LANDSAT satellite of resolution 15 m taken at 2010 and Google Earth with resolution 1 m taken at 2014.

4-7-1 Digital Elevation Model

The produced DEM is then used as a reference map layer for the other input layers after the validation of its accuracy.

The higher terrain of the region has led to an increase in the design of the landfill and running costs, so prefer areas that contain a few terrain, but preferably in the region that will be held by the landfill to be of slight slope so that pass through water and juices to be dealt with later, and therefore, the earth completely flat with the lack of any simple regression will sap gathering in which to increase the possibility of leakage of groundwater; then the area completely flat unsuitable also like steep because it will hinder the water that reaches them and lead to pass it collects. And it can be the same decline that exceeds 25% excluding land, the tendency of 5% is suitable for the establishment of waste dumps and longer (map (A-1)).

4-7-2 Settlement Area

By considering all the suggested safe distances in the literature, minimum distances for the study area are determined as 10 km for urban centers and 2 km for villages and 250 m for industrial areas. These distances are used to create buffer zones around settlement areas to evaluate the existing landfill in Khartoum and excluded from the study area map ((A-2), (A-3), (A-4)).

After exclusion of absolutely unsuitable areas for a landfill site, the remained areas are classified according to their suitability.

4-7-3 Roads

The roads are digitized from LANDSAT satellite, the layer of roads consists of Highway. The reason for this to applying different buffer zone distances according to the roads.

By considering these suggested values, minimum distances for the study area are determined as 2 km on both sides. This distance are used to create buffer zones around major road to evaluate the existing landfill in Khartoum and excluded from the study area, map ((A-5), (A-6)).

4-7-4 Airports

There is tow airport in Khartoum state, one is still under construction and will therefore focus on the existing airport that located in 4 km south east of Khartoum. The coordinates of the airport is read from the LANDSAT satellite and entered to the GIS environment. By considering these suggested values, the safe distance for an airport is determined as 3.000 m. This distance are used to create buffer zones to evaluate the existing landfill in Khartoum and excluded from the study area, map ((A-7).

4-7-5 Surface Water

Stream and main irrigation channels are digitized from the LANDSAT satellite map. The necessary buffer zone for stream is determined as 1 km on both sides.

By considering these suggested values, this distance are used to create buffer zones to evaluate the existing landfill in Khartoum and excluded from the study area map ((A-8).

4-7-6 Valley

To avoid what could result in flooding of the valley and the rush of the floods on the land of the landfill, and to reduce the possibility of contaminated surface water that comes out of the landfill on any water source, it is recommended to exclude any site is located within 300m of the waterway line from both sides effect.

By considering these suggested values, this distance are used to create buffer zones to evaluate the existing landfill in Khartoum and excluded from the study area map ((A-8).

4-7-7 Land use

The land use map obtained from a Merag company, imported to GIS environment, registered and then digitized. A database is created and attached to the map (Table 4-17). In the study area, there are six different land use types map ((A-9).

Table (4-17): Land use types and their rankings

Land Use Type	Symbol	Rating
Organized Industrial Area	QIA	0
Agricultural lands	AG	0
Urban Centers	UC	0
Villages	V	0
Stream & Channel	SC	0
Forest	F	5
Un occupied land	UL	10

4-7-8 Ground Water

Many researchers **[Akinbile and Yusoff, 2011; Longe and Balogon, 2010; Vasanthi et al., 2008; AbuRukah and Al-Kofahi, 2001]** have been examined municipal landfills possible impacts on groundwater resources by using microbiological examination and physicochemical analysis of landfill leachate and ground water. They explored that landfill sites are major threats for the ground water, local environment and communities as well.

4-7-9 Rain Fall

The higher rainfall increased the amount of water flowing, and the water that reaches the landfill body, and thus increase the amount of leachate, so do not prefer areas where rainfall rates are high. Thus when trade-offs between sites will take at least area of rain, the highest rank of the wetter areas.

4-8 Site Analysis

Digital Elevation Model (DEM) :

The DEM is the most important criteria in the selection of landfill sites. It has been re-classified in the map and given its rank as a common gauge (1-10) in order that less slope areas take ranks higher than those of higher slope. Thus, a slope of 5 % is the perfect one and I gave it rank 10, and that of more than 25% is the least suitable one and I gave it rank 1 , map (A-10) ,(A-11).

a- High way Roads :

It has been re- classified this map and give it ranks as common gauge(1-10)where data that gets the rank 10is the highest suitable to the landfills sits, while the data gets the rank 1 is the lowest suitable, map (A-12) , (A-13) .

b- Valleys :

As the above layers it has been re- classified this map and give it ranks as common gauge(1-10)where data that gets the rank 10is the highest suitable to the landfills sits , while the data gets the rank 1 is the lowest suitable, map (A-14) , (A-15)

c- Land use:

Convert the map to grid system (Raster) , and then work with grades of convenience so that the use of who gets the rank 10is the highest suitable to the landfills sits, while the use of who gets the rank 1 is the lowest suitable, map(A-16)

d- Mean Annual Precipitation:

After converting map of rain to Raster system it has been reclassified and give it ranks, has been give it ranks here gradually; areas with most rain took a lower rank, and areas with least rain took the higher rank, On the grounds that it reduces the amount of leachate that reaches the landfill, map(A-17)

e- Ground Water:

For groundwater such as the a above layer converting map of ground water to Raster system, it has been reclassified and give it ranks; areas with most ground water took a lower rank, and areas with least ground water took the higher rank, map (A-18)

4-9 The Relative Weight for Standards:

Already mentioned to a holistic view of GIS in assessing the suitability of the land for better planning landfill sites of various planning and processes , they are enjoying high flexibility by giving influential standards greater weight than the rest of the criteria , and therefore there are many tools that are used for this purpose , but we chose function of (**Weighted Overlay**) which enables the user to insert various weights provided that the total of 100% , and the ability to use this function in a (**Model Builder**).

We have adopted in the preparation of weights for different standards on personal experience, and read it for many Arab reference and foreign in this aspect, as well as consulting professor supervisor studying.

And finally been given access to all the standard a certain weight according to the degree of importance and influence so that equals the sum of the weights of 100 % and table (4-18) illustrates these weights

Table (4-18): The relative weight of the main criteria

No.	Standards	Relative weight %
1	Roads	30
2	DEM	10
3	Valley	30
4	Land use	18
5	Mean Annual Precipitation	6
6	Ground Water	6
7	River	Restricted

4-10 Build a structural Model :

In ArcGIS Pro, we can use geoprocessing tools to perform spatial analysis and manage my GIS data. Model Builder is used to create, edit, and manage geoprocessing models that automate those tools. Models are workflows that string together sequences of geoprocessing tools, feeding the output of one tool into another tool as input. Model Builder can also be thought of as a visual programming language for building workflows.

To build a geoprocessing model in Model Builder, add tools and data to a model view, and then make connections between them to establish the order of execution.

In this study, after determine the criteria and its classification, important, weighting, we build model in Arc GIS environment through Model Builder that depend on simplify complex problems and overlap in data and its relationship with the spatial and descriptive, So is the formulation of this model to simplify the basic problem and solve it through that called (flow chart) figure (4-2).

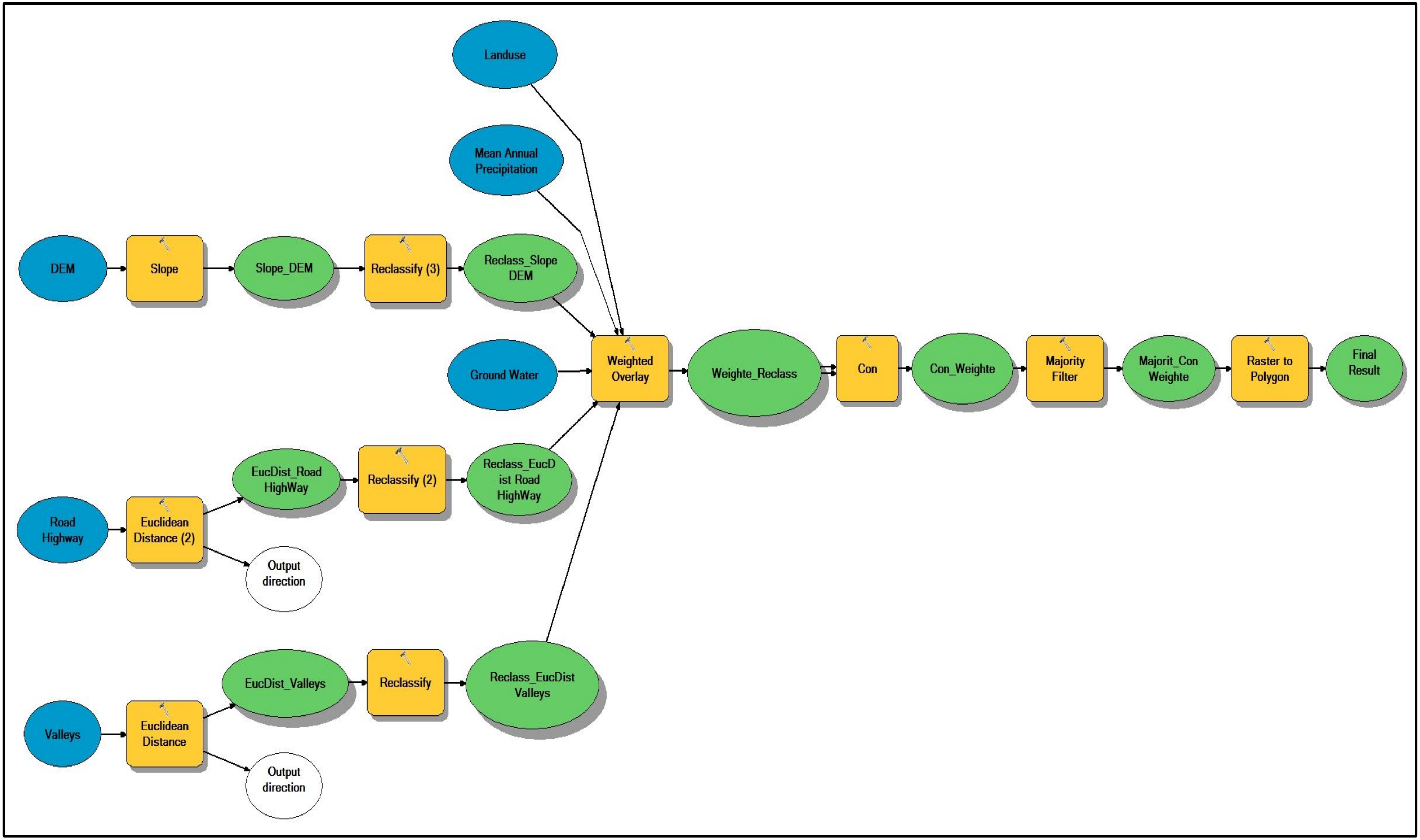

Figure (4-2): Model Builder

4-11 Conclusion for Suitability Map :

After the process of analysis and modeling in a GIS environment has been inferred knowledge with a map showing the best suitable landfill sites in Khartoum, the number 2 represent the least suitable , otherwise the number 6 represent most suitable. This study has been adopted in the output of these results on a wide range of criteria. This can be seen in the map (A-19).

After applying buffering, criteria and conditions set in the map (A-19), and exclude areas with less than 2 km^2, we have reached a map (A-20) that represents the color red, which more appropriate sites on the launch, reaching areas represented by the grades 6 (31 km^2), divided this site into two districts, giving them number 1 and 2. Then followed by the blue color in terms of the appropriate degree while the area of the grade 5 (1213.5 km^2), divided this site into nine districts and neglected those districts which are less than 2 km^2. The areas of these districts, their distance from the city center and the area coordinates are shown in the table (4-19) below.

Once the amount of waste generated has been estimated in chapter four, landfills should be designed in cells with sufficient capacity to receive the cumulative volume of waste generated. The optimal capacity of a landfill site should be no less than 5 years in order to ensure that the major investments required by the landfill are spread over large tonnage of waste.

The cumulative volume of wastes expected to be generated between 2014 and 2018 of selected landfills are presented in table (4-20).

Waste in the landfill should be covered daily by a daily cover in order to minimize health, safety, safety and environmental impacts and nuisances. The volume of daily cover in the landfill varies between 10% and 15% of the waste volume. Adopting a value of 10% of the waste volume, the required capacity of each landfill over the next 5 years can be estimated as shown in table (4-20).

Table (4-19): Suitable Area for Landfill

Option	#	Area km^2	Distance from center	coordinate E	N	Locality
6	1	27.5	51	398818	1747317	Um Badah
6	2	3.5	29	474238	1737321	Khartoum North
5	3	570.0	72	407904	1804261	Karary
5	4	3.7	82	391245	1787299	Karary
5	5	223.0	53	395486	1759130	Um Badah
5	6	8.9	31	417597	1736715	Um Badah
5	7	36.6	27	423049	1711272	Omdurman
5	8	264.0	43	472118	1772760	Khartoum North
5	9	23.6	71	510888	1765793	Khartoum North
5	10	40.4	38	483325	1749740	Khartoum North
5	11	44.0	25	472420	1741865	Khartoum North
SUM		1244.8 km^2				

Table (4-20): Yearly and Cumulative Waste Compacted Volumes

Year	Yearly volume of waste generated (m^3)	Cumulative volume of waste generated (m^3)
2014	2,448,573	2,448,573
2015	2,636,505	5,085,078
2016	2,832,796	7,917,874
2017	3,040,936	10,958,810
2018	3,257,921	14,216,731
+10% Cover	15,638,404	
Area m^2 3 m depth	5,212,801	