

# GIS-Based Analysis of Gold Mining in Sudan

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## ABSTRACT

Mineral resources represent an asset of the any country. It is the material basis for the national economic and social development, and it also represents an important basis of the production development and the protection for people's living standard. The ideal use of mineral resources will directly relate to the sustainable development of human society.

With the development of the GIS technology, mineral information resources can be ideally managed utilizing the capabilities of such system. This can increase the speed and quality of data processing, reduce the burden on staff and improve the level of office automation. How to make use of the advanced GIS technology to establish mineral resources management system has become one of the urgent problems for mining authorities.

The main objective of this study is to develop GIS database to manage gold resources in Sudan through investigating the mining status according to available data.

Data were collected from the relevant sources to develop the required GIS data base. Results showed that gold mining production is growing up. It is distributed over fifteen states out of eighteen. All gold mining states have traditional mining which has a significant impact. The Red Sea state comes at the top of gold production states in Sudan. Moreover, GIS can successfully be used to suggest new gold mining sites specially in North Kordofan.

**Keywords:** Concision companies, Geographical Information System (GIS), Gold, Mineral resources, Traditional mining, Sudan states.

## I. INTRODUCTION

Sudan has a huge mineral potential yet to be evaluated and developed. It has a long history and a big heritage of mining culture which go back

to three thousand years when Nubians extracted gold and base metals and smelted iron to make water wells. Sudan has different mineral resources which include petroleum, natural gas, gold, silver, chrome, asbestos, manganese, gypsum, mica, zinc, iron, lead, uranium, copper, kaolin, cobalt, granite, nickel, and tin.

Due to the desperate economic situation in the country following the secession of South Sudan in 2011, Sudan relaxed its minerals policy to encourage the production of minerals, attract investment in the mining sector, and increase foreign currency earnings from minerals, especially gold <sup>[12]</sup>.

In 2012, the ministry of minerals issued regulations on artisanal mining that covered issues such as registration, environmental protection, and the selling of gold to the bank of Sudan. Several other national laws are relevant to artisanal mining, including the Labor Act (1997), Environmental Protection Act (2001), Environmental Health Act (2009), Child Act (2010), and Minerals Wealth Development and Mining Act (2015).

Nearly one million Sudanese people work in the artisanal gold mining industry <sup>[6]</sup>. Over the years, gold mining has attracted farm workers and students at the expense of their respective trades. Studies by the Ministry of Minerals in 2014 and 2015 showed that 37% of artisanal gold miners were farmers and 27% were private business owners who had left their original jobs in search of quick wealth. It is possible to earn ten times more from gold mining than from farming or other professions <sup>[6]</sup>.

With the development of society, progress of science and technology as well as the world's population growth, the consumption speed of mineral resources has become faster, while mineral

resources prospecting has become increasingly difficult because of the improvement of the degree of geological work. To protect mineral resources and environment, it must increase the protection and comprehensive utilize of mineral resources, to strengthen the management of mineral resources. However, the current grass-roots mine authorities are widespread some shortage such as; the lag business office methods, the low level of information, the existing data cannot be effective use. Even if some areas achieve the information management but the resource data sharing are at low degree. The existing software is only based on the document management. Most of the managed maps based on paper, where there is no realization of digital map management.

## II. GEOGRAPHICAL INFORMATION SYSTEM

Geographical Information System (GIS) is an Information System (IS) for creating, maintaining, managing, and using geographic knowledge. It is an integrated platform for spatial data management and analysis whenever geographical information in digital form manipulated. It has been evolved in decision support in different disciplines such as engineering, urban planning, geology, agriculture, forestry, security, disaster management, and so on [9].

ArcGIS Desktop is a Geographical Information System (GIS) software that allows handling and analyzing geographic information by visualizing geographical statistics through layer building maps like climate data or trade flows. It's used by a whole host of academic institutions and departments, both in the humanities and sciences, to develop and illustrate groundbreaking research [14]. Further, it is used by several governments and private/commercial institutions worldwide.

The system has the capacity to create geographical information accessible throughout a company, institution, privately or publicly on the internet.

ArcGIS Desktop is comprised of a set of integrated applications, which are accessible from the start menu of computer: Arc Map, Arc Catalog and Arc Toolbox.

Arc Map is the main mapping application which allows to create maps, query attributes, analyze spatial relationships, and layout final projects. On the other hand, Arc Catalog organizes spatial data contained on computer and various other locations and allows search, preview, and add data to Arc Map as well as manage metadata and set up address locator services (geocoding).

Arc Toolbox is the third application of ArcGIS Desktop. Although it is not accessible from the Start menu, it is easily accessed and used within Arc Map and Arc Catalog. Arc Toolbox contains tools for reprocessing, data conversion, coordinate systems, projections, and more. This workbook will focus on Arc Map and Arc Catalog [13].

Therefore, the software essentially works as a platform whereby geographical information can be linked, shared, and analyzed.

## III. STUDY AREA

The Republic of the Sudan has a distinct geopolitical location. It located in the north-east of the African continent, bordered in the north by Egypt. South-Sudan in south. In the east by Eritrea and Ethiopia. Where, bordered From the West by Central African Republic and Chad. The area of the country is approximately 1882000 km<sup>2</sup>.

Sudan lies between longitudes 39°26'51".025 and 21°05'49".021 E and latitudes 23°42'15".172 and 08°07'47".419 N. The country has a distinctive geographical location, and it is rich with the many of natural resources includes rivers, agricultural lands, forests, oil, gas, and minerals, tourism and other resources that making it a distinct investment front.

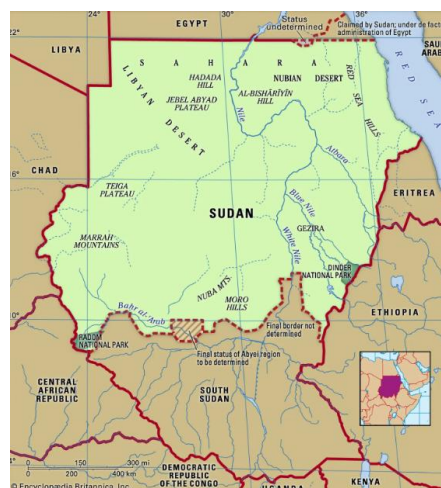


Fig. 1: Location of the Sudan

The Republic of the Sudan consists of 18 states including Khartoum, Northern state, River Nile, Red Sea, Qadarif, Kassala, Sinner, White Nile, Blue Nile, North kurdufan, South kurdufan, West kurdufan, North Darfur, South Darfur, Central Darfur, East Darfur, and West Darfur. Khartoum city is the capital of country.

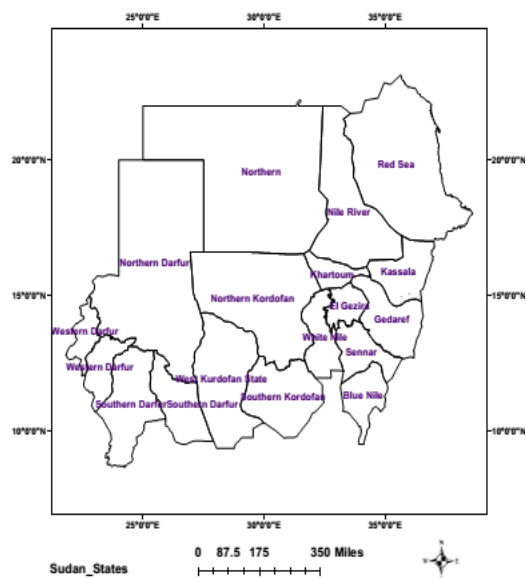


Fig. 2: Sudan states

#### IV. DATA

The data for this research was collected from number of relevant sources. Sudan Survey Authority, General Authority for Geological Research and Sudanese Mineral Resources Company were the main sources of data. The data included Sudan states map, gold distribution in Sudan and working companies. In addition to agricultural and residential maps. Table (1) below represents type of data and the main source.

Table 1: Type and source of data

Data	Main Source
Sudan states map	Sudan survey authority
Sudan residential map	
Sudan agricultural map	
Concession investment block map of Sudan	Geological research authority
Gold production data	The Sudanese mineral resources company

A detailed data about gold production in Sudan was provided by Sudanese Mineral Resources Company. This data classifies gold production into three categories: Concession companies, Mining waste companies and Traditional mining. According to available data, during the period from 2015 to 2020, Sudan produced more than 93 tons gold by average of more than 15 tons/year. Concession companies produced 38928 Kg with average production of 6488 Kg/year. Mining waste companies produced 54029 Kg with average of 9005 Kg/year. Traditional mining produced 193 Kg with average of 32 Kg/year. Table (2) below provide a detailed data about gold production in Sudan during the period 2015 to 2020.

Table 2: Gold production during the years 2015-2020

Years	Gold production (Kg)			
	Concession companies	Mining Waste companies	Traditional mining	Total
2015	4696	9983	-	14679
2016	6090	8987	29	15107
2017	6432	9196	53	15682
2018	7266	8515	61	15842
2019	8090	8901	21	17012
2020	6354	8447	29	14829

The figure below represents yearly gold production during the period 2015 to 2020. It can be noted that except year 2020, gold production is growing up in Sudan.

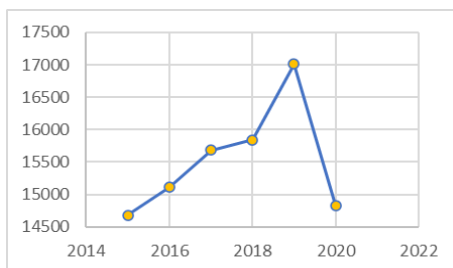


Fig. 3: Gold production 2015-2020

A detailed data about gold production during year 2020 was also available. A total of 14,830 tons of gold were produced in that year.

Monthly contribution of each sector in gold production during year 2020 is shown in table (3) below.

Table 3: Monthly gold production through year 2020

Month	Gold production (Kg)			
	Concession companies	Mining companies	Waste	Traditional mining
Jan	543.72	788.82	-	-
Feb	530.18	925.96	-	-
Mar	636.05	521.92	-	5.7
Apr	554.94	479.04	-	-
Ma	633.25	338.05	-	1.78
Jun	544.54	732.53	-	5.19
Jul	418	939.6	-	3.65
Aug	437.17	513.68	-	2.28
Sep	518	727.03	-	0
Oct	508	841.28	-	6.76
Nov	574.01	844.49	-	2.11
Dec	456.95	794.09	-	1.4
Sentence	<b>6354</b>	<b>8447</b>	<b>29</b>	<b>14830</b>

From the table above, it can be noted that traditional mining has a significant impact in gold production in Sudan.

Figure (4) below is a graphical representation of gold production during year 2020.

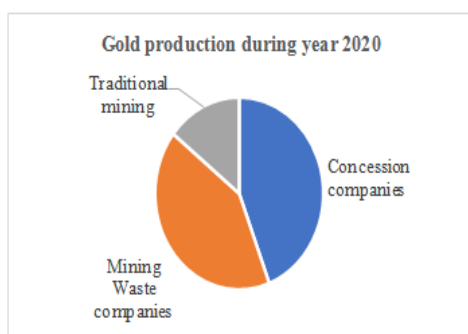


Fig. 4: Contribution of gold production sectors

By inspection of the above data, it can be shown that the average production of concession companies during the year 2020 was about 530

Kg/month. Where the average production of mining waste companies was 704 Kg/month. Traditional mining produced about 2.4 Kg per month during 2020.

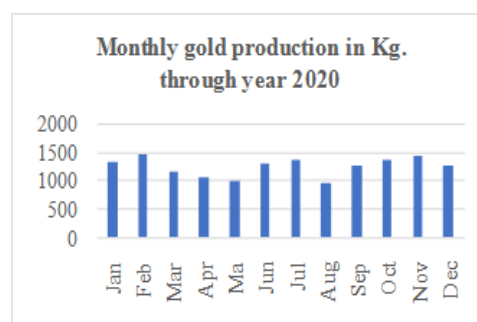


Fig. 5: Monthly gold production in 2020

Residential map was also provided by Sudan survey authority. This map represents distribution of residents over Sudan states.

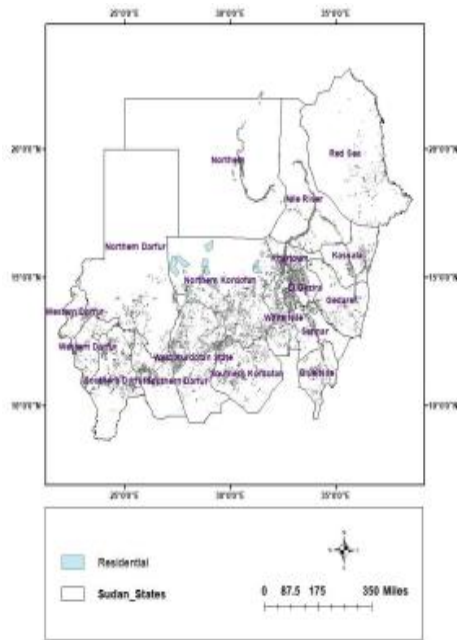


Fig. 6: Sudan residential map

Agricultural areas over the country were obtained as shown in figure (7).



Fig. 7: Sudan agricultural map

## V. METHODOLOGY

The approach of this research has been designed to use the GIS capability to reflect a real image of gold mining in Sudan. The spatial collected data were re-projected into CSC Sudan using ArcGIS desktop software. Google Map was used to capture JPE map format. A polygon features that representing concession investment

block in JPE map format were digitized after georeferencing has been carried out.

The Existing companies was captured from Open Street Map in OSM format and shape file format. Then topology was created for all layers.

Analysis of the existing data was carried out and proposals were suggested after applying the required criteria.

Figure (8) below is a workflow of the methodology adopted.

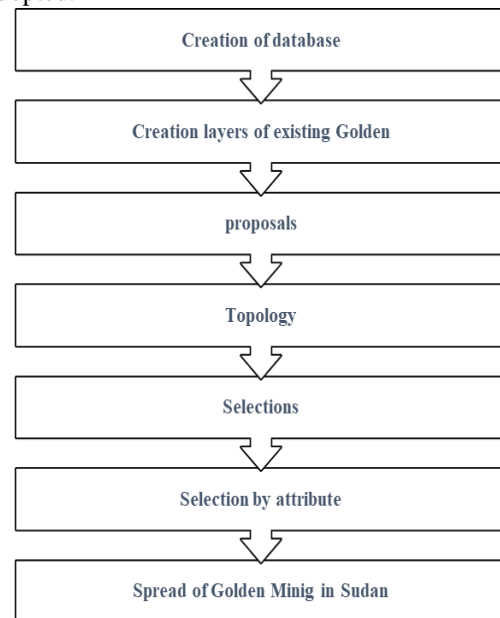


Fig. 8: Methodological approach

## VI. RESULTS AND ANALYSIS

First, a map showing the distribution of gold mining sites in Sudan states was created as shows in Figure (9) below. The map represents gold mining sites over Sudan states.



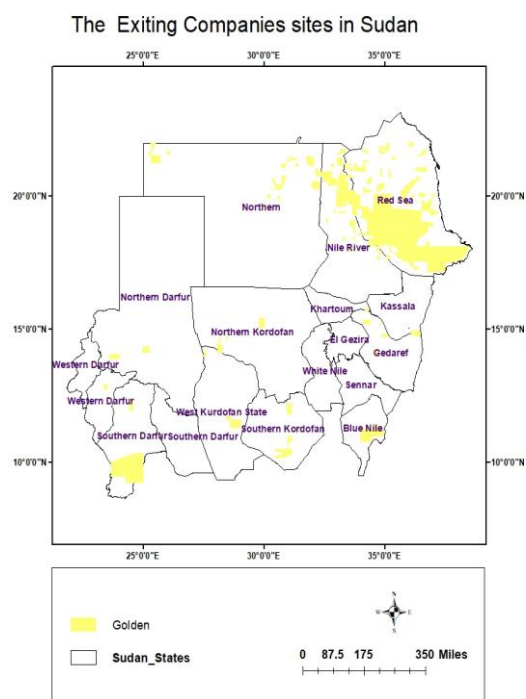


Fig. 9: Distribution of gold sites.

The chart below reflects the percentage distribution of gold throughout the states of Sudan.

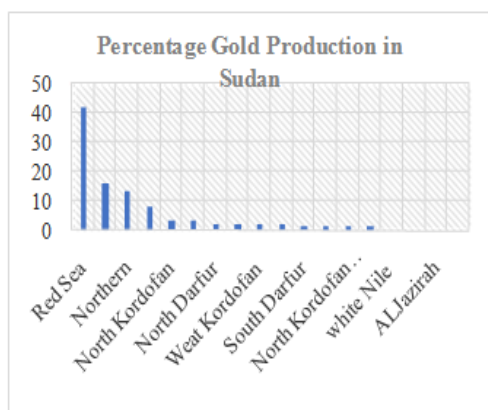


Fig. 10: Distribution of gold throughout the states

From the chart shown in figure (10) above, it can be noted that, gold in Sudan is distributed over fifteen states out of eighteen. The Red Sea state comes at the top of gold production states in Sudan, followed by Northern state and North Kordofan states. On the other hand, AL Jazira, Sennar and West Darfur states have no contribution.

ArcGIS was used to investigate the distribution of the gold concision companies over

Sudan states. Result obtained as shown in Sudan state map illustrated in figure (11) below.

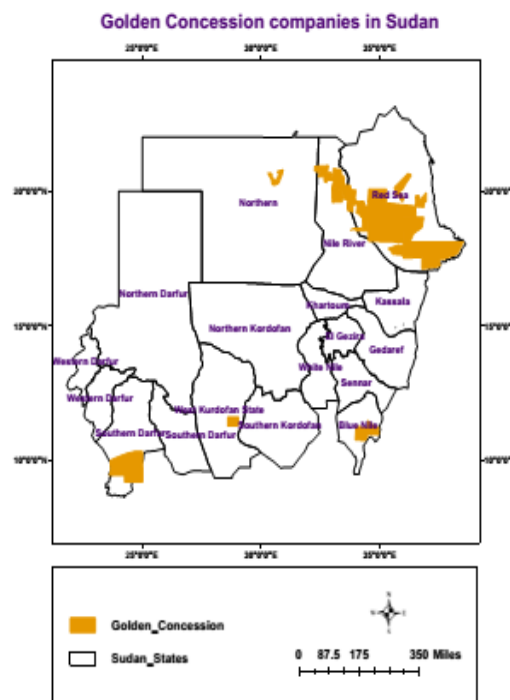


Fig. 11: Distribution of gold concision companies.

Results reflects that, concision companies are distributed over only seven states as shown in table (4) hereunder.

Table 4: Gold concision companies

State	No. of companies
Red Sea	10
River Nile	3
Northern	1
River Nile and Red Sea	1
West Kordofan	1
South Darfur	1
Blue Nile	1

Again, the Red Sea state come at the top of the list with 10 concision companies.

Traditional gold mining merged strongly in Sudan in last five year after Southern Sudan referendum, and after losing more than 70% of petroleum income. Although of its unhealthy and pollution impacts, it is widespread in number of states in the country.



Fig. 12: Traditional gold miners

Traditional companies over Sudan states were also analyzed using ArcGIS. Analysis showed that traditional mining spread over eleven states. Result obtained as shown in Sudan state map illustrated in figure (13) below.

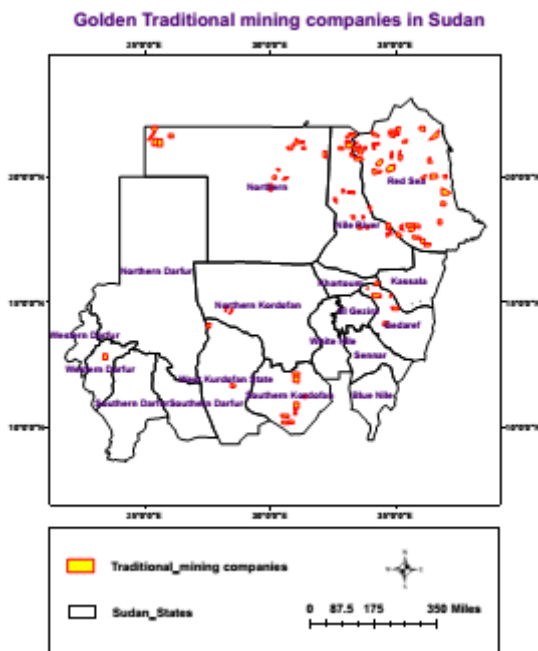


Fig. 13: Distribution of gold traditional mining

Although the Red Sea state monopolize production of Concision Company, it does so for tradition mining. Table (5) represents traditional mining over the states.

Table 5: States and traditional mining companies

State	No. of companies
Red Sea	37
River Nile	15
Northern	12
South Kordofan	9

River Nile and Red Sea	4
North Kordofan	3
Gedaref	2
North Darfur	2
Central Darfur	1
Weat Kordofan	1
Khartoum	1

The graph below arranges traditional mining via states.

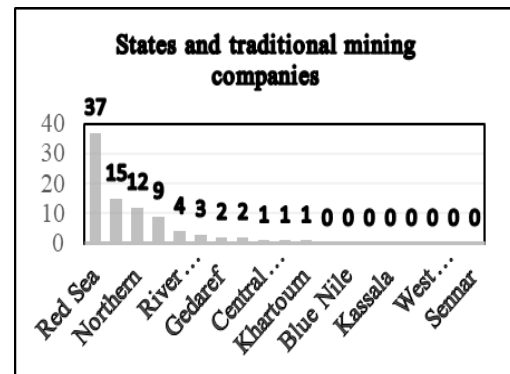


Fig. 15: Traditional mining via states.

Historically, much of the waste from mining activities has posed long-term liability issues with little or no economic value. But what if mining companies could recover the metals, like gold, and then sell them? The answer, these days, is obvious: they could reduce their environmental impact and, at the same time, contribute to a green economy.

To have a clear picture about companies mining on waste gold, ArcGIS was used to analyze the collected data. Result was obtained as illustrated in figure (16) below.

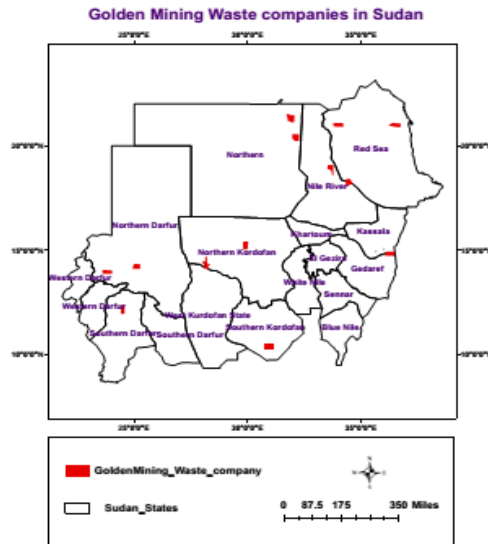


Fig. 16: Distribution of waste mining companies.

By investigating results and rearranging the attribute table, it can be noted that a total of 12 companies are working in waste mining. These companies are distributed over eight states.

Table 6: States and waste mining companies

State	No. of companies
Red Sea	2
Northern	2
North Kordofan	2
North Darfur	2
River Nile	1
River Nile and Red Sea	1
South Kordofan	1
Central Darfur	1

After analyzing the current situation of gold mining in Sudan, GIS was used to select new sites to implement additional companies.

New site selection subject to number of criteria such as to be near to gold sites and far from settlements and agricultural areas.

Adopting these criteria, 29 new mining sites were found. A map was created to show the distribution of new proposed locations for mining companies as shows in Figure (17) below.

The Proposed Companies sites in Sudan

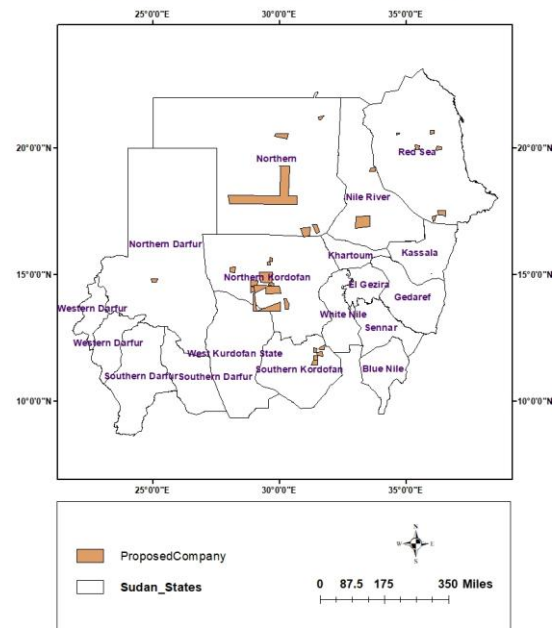


Fig. 17: Proposed locations for mining companies.

Proposed gold mining sites were distributed over six states as listed below. It can be obviously that, ten locations can be suggested in North Kordofan state.

Table 6: Proposed mining sites.

State	No. of sites
North Kordofan	10
Red Sea	6
Northern	5
South Kordofan	5
River Nile	2
North Darfur	1
<b>Total</b>	<b>29</b>

Figure (18) hereunder, represents exist and proposed mining locations over Sudan states.



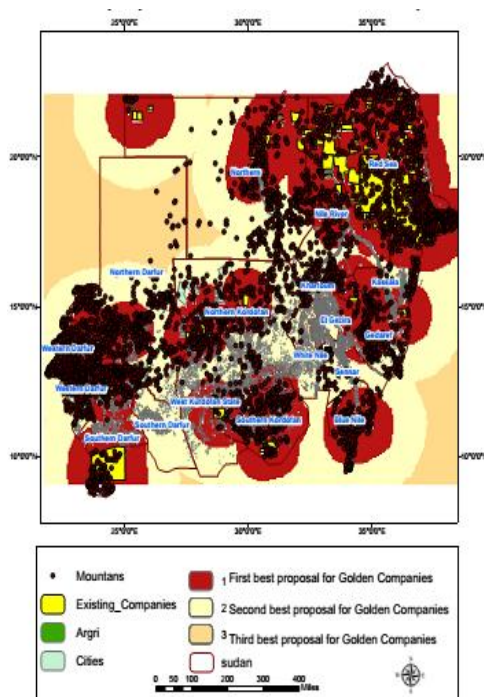


Fig. 18: Exist and proposed mining locations

## VII. CONCLUSION AND RECOMMENDATION

Countries that have mineral resource, usually have a good economic situation. Thus provide a sustainable development of human society. Unfortunately, this situation is inverted in Sudan.

This research work aimed to utilize GIS to analyze the current situation of gold mining in Sudan to reflect a real image. Then suggesting new location to extend mining activities.

From results obtained and analysis conducted it can be concluded with the following:

- Gold mining production is growing up in Sudan with average production of about 15 tons/year.
- Traditional mining has a significant impact in gold production.
- Gold in Sudan is distributed over fifteen states out of eighteen. The Red Sea state comes at the top of gold production states, followed by Northern state and North Kordofan states.
- AL Jazira, Sennar and West Darfur states have not gold resources.
- Concision mining distributed over seven states where waste mining distributed over eight states.
- Traditional mining is dominant in all gold production sates.
- New gold mining sites can be recommended using GIS capabilities.

- North Kordofan state is promising in gold production.

This study does not cover all factors affecting gold mining process. Therefore, it recommended to extend this work considering other critical factors. Moreover, the concept can be generalized for other mineral resources in Sudan.

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