The Republic of Sudan

Ministry of Agriculture and Forests

Forest National Corporation

Assessment of Implications of Gold Mining on Forest/Vegetation Cover and Water Resources in Sudan

By: Salih Ali Salih, PhD, Associate Professor of Geology

Leader

Consultancy Team:

Salih Ali Salih:	Associate Professor of Geology – Team Leader
Ahmed A. Salih:	Professor of Soil and Water
Intisar A. Salih:	Environment and Natural Resources Specialist
Sami Omer Hag El Khider:	Associate Professor of Remote Sensing and GIS .
Mohamed Noor:	M.Sc. Hydrogeology
Mrs. Baknam Adam	Statistician

Acknowledgment

We would like to thank the Staff of the Reducing Emissions from Deforestation and Forest Degradation Project Program (REDD+ Sudan) for their cooperation and assistance throughout this study. Thanks are due to The Sudanese Mineral Resources Company (SRMC) for facilitating the field trips. We are also indebted to the gold companies visited for accommodation and generous hospitality. The consultant team wishes to thanks Dr. Mohammed Abu Fatma and Dr. Mohammed O. El Gizoli for valuable insight. We thank the Forensic Laboratories in Khartoum for chemical analysis. Our gratitude extends to the enumerators and data entry team Talha Mohamed Yousif, Mohamed Ali Gafar, Ahmed Mohamed and Ithar Ali.

Acronyms

CBD: The Convention on Biological Diversity

CBS: Central Bank of Sudan

CSR: Corporate Social Responsibility

CNS: The Comprehensive National Strategy

DoDD: Drivers of Deforestation and Forest Degradation

EIA: The Environmental Impact Assessment

EMP: Environmental Management Plan

FAO: Food and Agriculture Organization

FNC: Forests National Corporation

GDP: Growth Domestic Product

GIS: Geographical Information system

GHG: Green House Gases

GRAS: Geological Research Authority of Sudan

HCENR: Higher Council for Environment and Natural Resources

HSE: Health, Safety and Environment

HSEMS: Health, Safety and Environment Management System

IFAD: International Fund for Agricultural Development

NAIP: National Agricultural Investment Plan

NDVI: Normalized Difference Vegetation Index

REDD: Reducing Emissions from Deforestation and Forest Degradation

SESA: Strategic Environmental and Social Assessment

SMC: Sudan Mining Code

SMRC: Sudanese Mineral Resources Company

SNRP: Sudan National REDD+ Program

UNESCO: The United Nations Educational, Scientific and Cultural Organization

UNFCCC: United Nations Framework Convention on Climate Change

UTM: Universal Transverse Mercator

WCGA: The Wildlife Conservation General Administration

WHO: World Health Organization

Executive Summary

The main objective of this study was to assess the impact of gold mining on natural resources specifically on forests, agriculture, wildlife, soil, water, and rangeland. The study was conducted in three states where extensive mining activities are ongoing. The sites selected have different natural resource bases, thus Abydia area, Gold-bearing state, El Subagh and Um Saqata, Gadarif state, and Belgawa in the Blue Nile State were selected. Ariab government mining company in the Red Sea state was visited as a leading company with high production standards.

Secondary data from an extensive literature review of related policies, regulations, and stipulations under different related conventions and international agreements were consulted. Relevant reports from the Ministry of Energy and Mining as well as from government officials at national and local levels were also sought. Primary data was collected from questionnaires addressed to local communities in the vicinity of mining sites, gold ore processors, artisanal miners, and mining companies. Remote Sensing and GIS techniques were used in two selected areas (Belgawa, Blue Nile State & Um Saqata, Gadarif state) to trace, delineate and evaluate the changes in the vegetation cover and the degradation of the flora in the mining areas for the time span 1999-2019. Water samples were collected from boreholes, hafeers, and the Gold-bearing in mining areas. Soil samples were collected from topsoil in the mining sites. Samples were analyzed using ICP (Inductive Coupled Plasma) analytical technique for heavy metal content. The data collected were statistically analyzed using SPSS statistical package.

The study showed that mining activities have resulted in physical, chemical, biological, and social damages that need to be addressed. There is a clear physical disturbance of land surface rendering it prone to wind and water erosion, removal of fertile topsoil, creation of pits hazardous to humans and animals, and reduce land suitability to other uses. Chemical pollution by mercury, cyanide, and other heavy metals especially at the processing sites inside market complexes is evident. Biological damage including tree removal, disturbance of species. Mix, disturbance of soil fauna and flora, destruction of the soil seed bank, destruction of habitat for wildlife, reduction of rangeland area, and usability is confirmed by the study.

Communities in visited sites are of the opinion that mining is very destructive to forest resources. Miners use forest resources as a source of energy and wood for huts construction. Out of work artisanal miners get engaged in charcoal making and firewood collection. Strong woods poles are used as underground mine support. These activities support tree felling, deforestation and land degradation around mining sites and beyond. Mining activities inside and close to forests caused disturbance of tree species mix. Species such as Talih (A*cacia seyal)* and Sahab (*Anogeissus leiocarpus)*, Habeel, (*Combretum hartmanianum),* Ebony (*Diospyros spp*) and Hashab (*Acacia senegal*) have disappeared or are rarely seen around the mining sites. In Belgawa Ebony (*Combretum hartmanianum*) was targeted by miners for underground mining support.

The area around Belgawa site was severely impacted, from 10,000 feddan understudy about 310 feddans were completely cleared and the tree density was critically reduced in about 4170 feddans, however, inaccessible areas showed some increase in vegetation cover. In Um Saqata

area, a similar trend was observed where 17% of the area showed some decrease in vegetation cover and 64% no change, and about 19% showed a slight increase in vegetation cover. It should be noted that agriculture is still the dominant factor in deforestation in both areas.

The indirect impact of mining on forests includes infrastructure development such as roads which could lead to exploitation of forests for commercial firewood and charcoal; high population influx in previously inaccessible areas imposing high pressure on natural resources; increased hunting and poaching of wildlife, conflicts over land use between landowners and miners documented by the frequently reported incidents in most mining sites

Regarding rangelands, the communities around mining sites feel that their rangelands disappeared, reduced in area or degraded. Miners and companies, however, don't see any negative impact. Communities also think that the grass species combinations were completely altered where palatable species were extinct such as Difra (*Sporobolus pungens*) and Sedges (*Syperus spp*). Species of low nutritive value were taking over such as Puncture vine (*Tribulus terrestris*). Mining pits created by artisanal miners is another danger for community livestock. In the Blue Nile surface disturbance renders the land unsuitable for any land use.

Wildlife is highly linked to forests which provide habitat shelter and food. 96% of the communities surveyed agree that wildlife either completely disappeared or was greatly reduced. Several species which are commonly seen in the near past have disappeared, mammals such as Gezal, Fox, Monkey, Wild Cat, are no longer seen, while birds such as Houbara Bustard (Chlamydotis undulate) and Wild Chicken (Gallus gallus) also disappeared. Explosives used in mining drive wildlife away, poaching is practiced by some miners and extreme droughts impact wildlife severely. There are several reports of mammals falling into open mining pits, and there are birds poisoning by cyanide used by big companies.

Forests and rangelands were severely impacted, and this reflected heavily on browsing livestock especially sheep and goats while camels and cows were less affected probably because they are able to tap rangeland away from mining sites. The carrying capacity of rangelands was much reduced and this was reflected on productivity of milk and meat and a low birth rate.

The boom of mining in the last two decades threatened agriculture widely. The community thinks that there is a reduction in area available to agriculture as well as a reduction in yield. Mining disrupts the soil surface rendering it unsuitable for agriculture, the huge volume of mining wastes usually deposited on-site containing significant levels of toxic substances making it unsuitable for agricultural practices. The topsoil most fertile was destroyed. The construction of access roads to mining sites disturbs agricultural lands as well. About 8% of the community abandoned agriculture altogether. The main effect of mining on agriculture is the unavailability of labor. Labor migration to mining areas is very intense which increases labor cost and consequently increase the cost of production.

Perhaps the most significant impact of mining is on water quality. More than 50% of communities interviewed feel that their drinking water was contaminated to the extent of affecting both human and animal health. Observations in Abydia area reveals that the main pumping station for the town is located downstream very close to where mining heavy trucks, excavator, etc.. are washed near the Nile and drainage water flows directly into the Gold-bearing. The community attributes many of the chronic human diseases to water pollution. In Belgawa area, the community complains about drainage water from the mining site entering their main drinking water source. Water samples analyzed indicated that it is heavily contaminated with heavy metals. Contents of Cadmium, Nickle, Lead, and Mercury are well beyond the threshold limits set by WHO. Soil is also polluted with heavy metals near mining projects. Mining wastes, tailings and overburden piles are exposed to wind erosion which can contaminate areas far away from the mining site.

Most mining companies interviewed don't have any reclamation plans when mining operations ended to restore the quality of land to their pre-mining levels and to restore the ecosystem services and conserve forests and wildlife habitat. It is required that sufficient funds be available for reclamation. Collaborative efforts of mining companies, government and conservation organizations are necessary to promote successful mine reclamation. Although relevant laws and legislations exist (SMRC 2017), they are not enforced. This study recommends the use of water harvesting techniques to increase tree survival and suggests to plant drought-tolerant trees such as Acacias in central and southern Sudan mining sites. In fragile ecosystems, archeological sites and atheistic sites, "**no-go-site**" should be created where mining should be strictly prohibited.

There is a lack of a comprehensive policy and legislative framework that deals with land use in an integrated manner. However, there are a number of individual sectoral policies such as agriculture, forestry, wildlife, mining, oil and other resources. There is an urgent need to review natural resource policies to accommodate the impact resulting from the recent outburst of mining. This also includes identification of no-go-zones for mining. There is also a need to establish and enforce new policy/law stipulations to reduce the impact of artisanal mining on the environment. Furthermore, there is a critical need to review the licensing procedure for mining at the Federal and State level to ensure enough scrutiny and clearance of relevant natural resources authorities. Mining projects may create jobs, roads, schools, and increase the demands of goods and services in remote and impoverished areas, but the benefits and costs are unevenly shared. Communities in visited sites feel they are being unfairly treated or inadequately compensated by mining projects rather, this has led in many cases to social tension and violent conflicts.

This study recommends that natural resources institutes, local authorities, and communities should engage in joint monitoring of mining activities to detect early signs of deforestation and land degradation and water pollution. This recommendation should be overseen by the Higher Council of Environment and Natural Resources where heads of all these relevant institutions are members. Regarding artisanal mining, there is a need to mainstream artisanal mining into the country’s economic plan and to establish a comprehensive legal framework including policies, laws, bylaws, and legislation to govern, regulate, and control the artisanal mining in Sudan. Formalization of the artisanal mining sector will lead to greater transparency and control of conflicts. It will also help in introduction of environment-friendly technologies and new approaches to ensure safety and environmental protection and health measures to reduce the adverse effects of mining by adopting best mining practices.

Table of Content

List of Tables

List of Figures

1. Chapter 1: Introduction

1.1. Background

The Republic of Sudan is home to about forty million people (2016). Like in other African countries, livelihoods in Sudan depend heavily on soil, water, and vegetation resources. Economic diversification and overall macroeconomic stability in Sudan need to be fostered in light of the declining revenues from oil. Sudan is endowed with minerals that contribute to the country's economic development. However, mining is also a major source of degradation of the physical as well as social environment. Additional environmental issues including deforestation and unsustainable natural resources management practices in and around gold mining areas, as well as conflicts with wildlife, may potentially be significant given the recent increase in gold mining activities across the country. Concerns relating to the mining-forest-wildlife nexus have not been assessed or addressed to the extent that would seem adequate.

Sudan continues to face a myriad of climate-induced natural hazards and socio-economic pressures including localized flooding and drought, crop failure and insecurity resulting from reduced early harvests, low food stocks, persistently high prices, civil unrest, restricted access to agricultural land and food, and an increasing influx of climate-induced refugees and internally displaced persons. In North Kordofan, large tracts of land were cleared of Acacia species for agriculture, depriving the local poor of a sustainable source of income from the production of Gum Arabic. In the Northern State, drifting sand dunes have affected viable agricultural lands along the Nile valley and in some places reaching the Gold-bearing. Sustainable management of the natural resource base has thus become not just an environmental issue but one related to stability, peace, and security in light of increasing climate threats. This is equally true for central and southern Sudanese states where the potential for resource-based conflicts on natural resources and unclear land tenure, is high. This situation in most of Sudan made gold mining a lucrative business and hence the outburst of gold mining as a source of income and employment.

Since demand for gold is set to continue to grow, a sound understanding of the impact of gold mining on natural resources is needed and policy measures that can mitigate any negative impacts and help ensure that the mining sector makes a positive contribution towards sustainable development are required. Mining-related disruption can impact the environment through contamination of surface and groundwater, loss of habitat, etc. Some negative social and environmental impacts are avoidable if mining is conducted according to the best possible standards.

The gold mining boom in Sudan has started in 2005 and is now going in many parts of the country. Very few studies were conducted to evaluate mining impacts on natural resources. There has been an increasing focus within the international environmental community to address drivers of environmental degradation, rather than symptoms. This has resulted in many conventions and treaties that attempted to address such degradation.

1.1. Mining-related International Conventions and Treaties

Mining is controlled by many laws and international agreements that were ratified by the Sudan Government in areas such as biodiversity, climate change, human health, environment, and wildlife. There are also laws governing the use and transport of toxic chemical substances. Some of these laws are summarized below.

1.2.1. Minamata Convention

The Minamata Convention on Mercury (2013), intensively used in gold extraction, is a global treaty to protect human health and the environment from its adverse effects. The Minamata Convention entered into force on 16 August 2017 and Sudan has signed in 2014. The Convention draws attention to a global and ubiquitous metal that, while naturally occurring, has broad uses in everyday objects and is released to the atmosphere, soil, and water from a variety of sources. Controlling the anthropogenic releases of mercury throughout its lifecycle has been a key factor in shaping the obligations under the Convention. Major highlights of the Minamata Convention include a ban on new mercury mines, the phase-out of existing ones, the phase-out and phase-down of mercury use in a number of products and processes, control measures on emissions to air and on releases to land and water, and the regulation of the informal sector of artisanal and small-scale gold mining. The Convention also addresses interim storage of mercury and its disposal once it becomes waste, sites contaminated by mercury as well as health issues.

1.2.2. The Basel Convention

The Basel Convention was adopted in 1989 and entered into force on 5 May 1992. The overarching objective of the Basel Convention is the Control of transboundary movements of hazardous wastes and their disposal, to protect human health and the environment against the adverse effects of hazardous wastes. The Protocol on Heavy Metals, a protocol to the Convention on Long-Range Transboundary Air Pollution, was adopted in Aarhus, Denmark in 1998. The Protocol addresses the reduction of cadmium, lead, and mercury emissions in the interests of environmental protection. Amendments to the Protocol were agreed to in 2012 to introduce more stringent emission limits but are not yet in force.

1.2.3. Convention on Biological Diversity

The Convention on Biological Diversity (CBD) which was signed by Sudan is an international legally binding treaty with three main goals: conservation of biodiversity; sustainable use of biodiversity; fair and equitable sharing of the benefits arising from the use of genetic resources. The Convention was opened for signature at the Earth Summit in Rio de Janeiro on 5 June 1992 and entered into force on 29 December 1993.

1.2.4. Convention on Climate Change

The Kyoto Protocol is an international treaty that extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that commits state parties to reduce greenhouse emissions. The main goal of the Kyoto Protocol is to control emissions of the main anthropogenic greenhouse gases (GHGs) in ways that reflect underlying national differences in GHG emissions, wealth, and capacity to make the reductions. Currently, there are 192 Parties (191 States and 1 regional economic integration organization) to the Kyoto Protocol to the UNFCCC.

The Kyoto Protocol operationalizes the United Nations Framework Convention on Climate Change by committing industrialized countries to limit and reduce Green House Gases (GHG) emissions in accordance with agreed individual targets. The expansion of roads and railways driven in part by extractive industries remains one of the biggest threats to natural habitats and wildlife populations and will increase access to some of the world's most biodiversity ecosystems. In Gabon, for example, the Belinga iron-ore deposit sits deep within the Congo rainforest and will require the construction of a 240-km railway line (Ash, 2013), whereas in Tanzania, a proposed road to the goldfields by Lake Victoria could bisect the Serengeti National Park and disrupt one of the world's greatest surviving terrestrial wildlife migrations (Dobson et al., 2010). Extractive industries also attract a rush of migrant people from outside the mining areas in search of work or to undertake small-scale artisanal mining.

The Paris Agreement on climate change (2015) sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. It also aims to strengthen countries' ability to deal with the impacts of climate change and support them in their efforts. In this regard, mining as one of the drivers for deforestation and land degradation need to be carefully planned and managed.

The Espoo Environmental Impact Assessment (EIA), entered into force in 1997. The Convention sets out the obligations of parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the general obligation of states to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across boundaries. Unfortunately, Sudan did not sign this convention.

During the UNFCCC COP-13 in Bali, the international community has called upon countries to explore the concept of Reducing Emissions from Deforestation and Forest Degradation (REDD). Recently, the concept has been expanded to include conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks (REDD+). In this context, the Republic of Sudan considered the REDD+ mechanizm to be a priority area for development in the conservation and management of forest resources and rangeland in the country. The Government in collaboration with a wide range of key stakeholders has established the Sudan National REDD-Plus Program (SNRP).

To support the implementation of the SNRP particularly the REDD-plus readiness phase, the Republic of Sudan has received a grant through the Forest Carbon Partnership Facility of the World Bank to support Sudan in preparing for the implementation of its National REDD+ Program.

In line with the country’s efforts towards forest conservation and the development of appropriate policy and instruments for pursuing REDD+ as foreseen under the SNRP, the Project supported the conduct of many specialized studies, one of which is the In-depth Analysis of Drivers of Deforestation and Forest Degradation, (2018). The DoDD Study concluded that agriculture, urban sprawl, infrastructure development, petroleum exploration, mining, and refugees and internally displaced people are the main direct drivers. The study has ranked mining as number five among the six identified drivers. Hence, this study is proposed to undertake an in-depth analysis of the effect of gold mining on forests/vegetation cover and water resources in Sudan. The focus on gold mining among other mining activities is that recently gold mining became a major economic and social activity in the country.

1.2. Objectives of the study

The overarching objective of this consultancy is to assess the impact of artisanal gold mining on natural resources, specifically on forests, wildlife, soil, water, and rangeland. The study will also touch on the impact on human health and welfare and possible reclamation techniques of degraded mining sites. The specific objectives were to:

- Assess the scale and types of impacts caused by gold mining on natural resource management in Sudan on forests/vegetation, water resources, and soils; land use-based interventions including agriculture and livestock management.
- Assess the scale and types of impacts caused by gold mining on indigenous people, local communities, youth, and children and any gender implications.
- Present an analysis pertaining to the mining-forest-wildlife nexus that can help inform future investments in Sudan. Such investments would aim to tackle the drivers of environmental degradation.
- Analyze risks and trends in the environmental and the socio-economic consequences of mining activities.
- Establish the contribution of mining/minerals to the local and national economy
- Provide outlook and analysis of the potential approaches to greening in a way that mitigates greenhouse gas emissions, combat soil erosion, desertification, and environmental pollution.
- Assess and provide recommendations for addressing policies, legislations and regulatory gaps.

Chapter 2: Location and Methods of the Study

2.1. Physical Environment of the study area

2.1.1. The Gold-bearing State

The Gold-bearing State lies between Longitudes 32°-36° E and Latitudes 16°-22° N. The state is boarded by Egypt from the north, Northern State from the west, Khartoum State from the South and the Red Sea State from the east. The total area of the State is 12.94 million hectares, 68.9% of this area is desert or semi-desert. Temperatures as high as 48ºC are experienced during the summer, while lowest temperatures are about 8ºC. Annual rainfall is 50 to 60 mm. Potential evapotranspiration is about 3000 mm annually. Most of the land away from the Nile is marginal of low fertility.

The most salient feature of the State is the Gold-bearing and Atbara River. Agricultural activities mostly concentrated on the banks of these two rivers. The state is famous for the production of horticultural crops and some winter crops like wheat and horse beans (*Viciafaba*). Agricultural production near Atbara River is mainly for food security. Some rainfed grazing areas are found in the valleys away from the Nile and Atbara Rivers. Out of the total area of the state, agriculture represents (2.4 %), rangeland (2.6%), forests (1.6%), and desert (69%), (Africover, FNC, 2008).

Overall, there are about 43 forests reserves along Atbara River with a total area of 52360 feddan hectares. Along the main Nile, there are two forests reserves in Wad Bannaga and wad El Nur with a total area of about 71400 Feddan. An area of about 5400 hectares was recently reserved around Musawarat and Nagaa historical sites. The main Nile and Atbara Rivers are the main water resources of the State. However, 50% of the State is underlined with Nubian sandstone rich in groundwater estimated at 300 billion m^3, of which only 80 million m^3 is utilized at present.

The Gold-bearing State is inhibited by 905,000 people (2003). Eighty percent of the population depends on agriculture for their livelihoods. Agriculture is practiced on the narrow strips of fertile soil along the Nile and Atbara Rivers. There are about 448,400 heads of sheep, cows, goats, and camels of good breeds.

The key environmental concerns in the Gold-bearing state are desertification and sand dune encroachment and riverbank erosion. These are aggravated by some of the current land uses and intensive mining activities.

2.1.2. Gadarif State

The total area of Gadarif State is about 5.8 million hectares. The State is located in eastern Sudan between latitudes 12°39'36" – 15°45'36" and longitudes 33°34' 12" - 36° 33'36". Gadarif State is bordered by Ethiopia on the East, shares its border with four other states, namely Khartoum, Gezira, Sinnar, and Kassala. The state is characterized by an arid and semi-arid climate with summer rainfall ranges from 200mm to 900mm per annum. The State has a flat or undulating topography and various vegetation communities ranging from short grass shrubs to Acacia woodlands and mixed forests. The total forest cover was estimated at 1.5 million ha (18% of the total State area) out of which 612,508 ha are forests reserves. Soils are mainly heavy cracking clays. The major land use types are mechanized large-scale farming, smallholding traditional farming, and pastoralism. Forest utilization is important in the State; the per capita consumption of wood-based forest products is equal to 0.71 cubic meters.

The dominant tree species in the state are *Acacia seyal*, *Balanites aegyptiaca*, *Acacia mellifera*, *Acacia senegal*, *Combretum hartmannianum*, *Anogeissus leiocarpus* and *Entada sudanica* occur together with *Boswellia papylifera* specifically in hill slopes and soils formed in sites around the hills.

Soil deterioration and land degradation are evident in both mechanized and traditional farming areas due to the mono-cropping of sorghum. Large-scale forest removal is mainly attributed to mechanized agriculture, fuelwood production, charcoal making, and overgrazing. This fact was confirmed by the DoDD (2018) which depicts that agriculture is the main driver of deforestation and land degradation.

Massive tree removal for mechanized rainfed agricultural started in the mid-forties of last century by only about 500 feddans and currently exceeded nine million feddans. Forests clearance accelerated wind and water erosion, deteriorated soils, increased drought effects and reduced ecosystem productivity. There is an evident need for a large-scale forestry program to rehabilitate the degraded forest reserves, reintroduce forest trees in the vast mechanized agricultural land in form of woodlots and shelterbelts in order to improve microclimates and reduce soil erosion caused by the mal-practices of continuous land preparation.

Being home for different acacias species Gadarif is famous as a traditional charcoal production area and Rahad riparian forests are also famous for being traditional firewood production areas. The area hence experienced vast tree removal for providing energy to various parts of the country.

Moreover, refugee influx from adjacent countries into Gadarif area is another cause of severe tree removal and negatively affected the environment through home construction activities and other wood consumption aspects.

2.1.3. Blue Nile State

The Blue Nile state is located in the southeastern part of Sudan between latitudes 12°35' and 9°30' N and longitudes 35°8' and 33°8' E with an area equal to 8,500,000 feddans (38,500 km^2). Twenty percent of the area is water, 30% forest and rangeland, and 40% mechanized agriculture (Blue Nile Investment Map 2004). The Blue Nile State is bounded by Ethiopia from the east and southeast, Sinnar state from the north east and Upper Nile from South Sudan.

The main topographic feature is the southern central clay plain which was deposited by the Blue Nile, the clay content can reaches more than 60%. The soil is heavy-cracking clay with very low permeability. The central clay plain slopes gently to the north. The study area lies within the savannah zone which is characterized by an average rainfall ranging from 300-800 mm/annum. The maximum temperature is between 31.2°C-40.6°C while the minimum temperature is between 16.6°C-24.8°C. The vegetation is characterized by wide diversity depending on rainfall, soil type, and flooding of the Blue Nile. The tree vegetation is divided into three categories as follows: Kittir belt: The kittir belt with rainfall between 300-570 mm/annum concentrated in heavy cracking clay plain that lies in the north. The dominant tree species in this region include *Acacia mellifera* (kittir) *Acacia nubica* (laoot). Higlig and Taleh belt: This belt extends in rainfall between 570-800 mm /annum, located south to the Kittir belt, on heavy clay soil. The dominant tree species are *Acacia seyal* (taleh), *Acacia seyal* verity *fistula* (suffer), *Acacia Senegal* (hashab), *Acacia polycantha* (kakamout) and *Balanites aegyptiaca* (hijlij). The Sahab and Habil belt: South of the Hijlij-Taleh belt where the rainfall is more than 800 mm/annum, the dominant tree spp are *Anogessus leiocarpus* (sahab), *Pterocarpus indica* (taraya), *combretum hartmannianum), Terminalia brownii* (droat), and other broad-leaved tree species. The species which are found on slopes or lower parts of hills or mountains are *Sterculiase tigera* (tartar), *Boswellia papylifera*. The riverine forests: These are found in flood basins along the Blue Nile, where main species include *Acacia nilotica* (Sunut) growing in pure stands in maays, the high contours occupied by dahara tree species like hijlij, loat, dalaib, koke, aradaib and the gerf where the dominant species includes *Acacia nilotica* (sunut) *Eucalyptus* species (kafoor), *Khaya senegalensis* (Mahogany), *Conocarpus lancifolis* (dammas), *Cordia Africana* (anddrab), *Oxtenanthera abysinica* (ganna) are found in plantations. These tree species are planted and well managed. In the past and before the 1960s most of the state was covered with much denser tree vegetation, estimated to cover 75% of the total area. The vegetation was later subjected to severe destruction particularly the natural forest resources, due to so many factors such as the establishment of Ruseris dam in 1960s that resulted in the removal of large numbers of trees along the river and large scale mechanized rainfed agriculture introduced in 1975. The increase in the population influx of large numbers of displaced people escaping from the war, and drought from western Sudan, construction of the highway that facilitated the transportation of the wood products are also factors affecting the natural resources in the state. All these factors lead to extensive logging and clearing of forest trees and lead to severe degradation. (Blue Nile Investment Map 2004).

2.2. Location of the Study Area

The study on the effect of mining on natural resources was conducted in three states. The sites were selected mainly to represent areas where extensive mining activities are going on. The second criteria were the representation of different ecological features and natural resources base. Consideration was also given to the type of mining activity (artisanal, private sector). Based on the above criteria, the following sites were visited (Fig.1):

1. Abydia area, Gold-bearing state.
2. Al Subagh and Um Saqata, Gadarif state.
3. Belgawa, Blue Nile state.

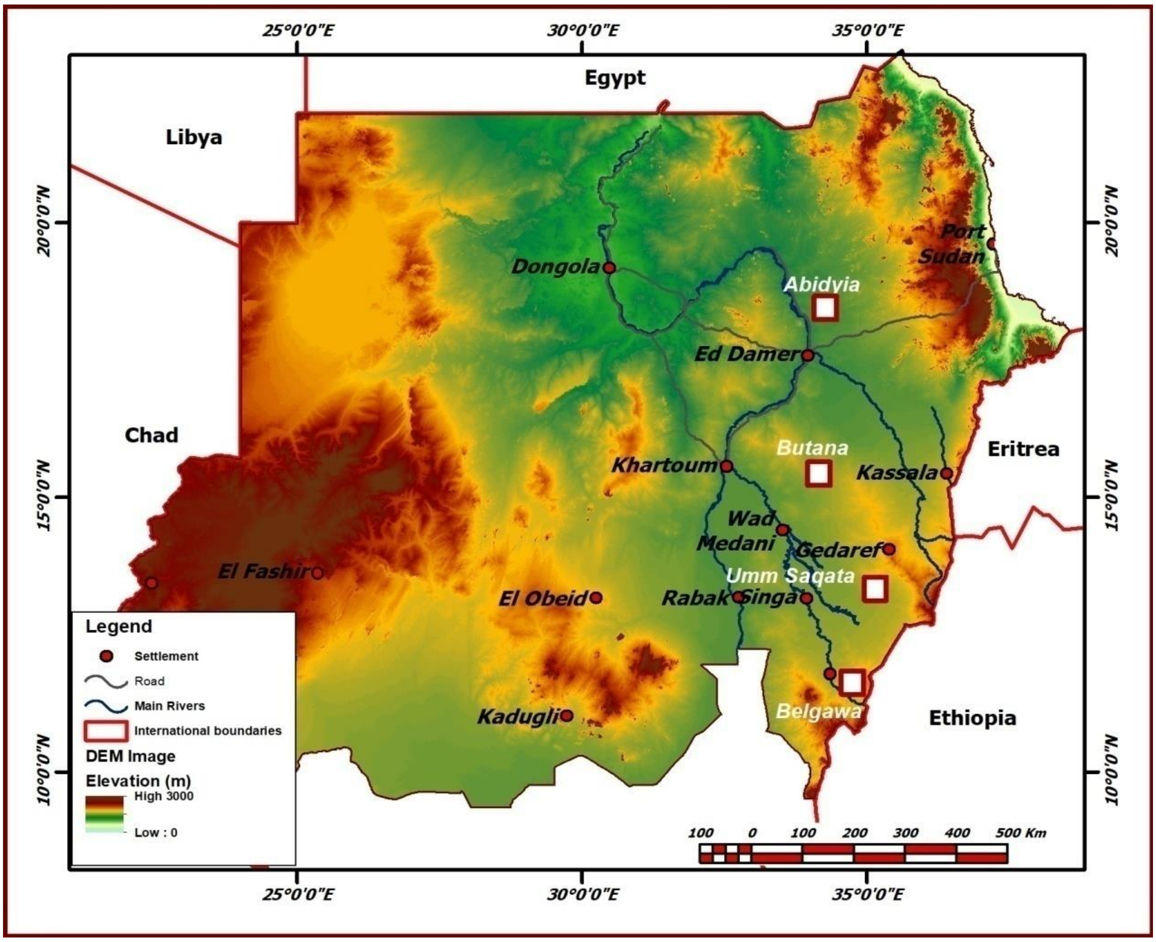


Figure 1: location Map of the Study Areas.

Ariab Gold Mining Company in the Red Sea State was visited as a Government leading company with high mining standards.

Secondary data from an extensive literature review of related policies, legislations, and stipulations under different related conventions and international agreements were consulted. Data from the reports of the Ministry of Energy and Mining as well as from Government officials at national and local levels was also consulted. This has also included relevant reports, studies, and literature pertaining to mining.

2.3. Data Collection Methods and Tools

Primary data was collected using the following methods and tools:

2.3.1. Questionnaires

The questionnaires were designed mainly to seek the views and perspectives of the following selected groups (Appendix 1):

A- Local communities living in the vicinity of the mining sites.

B- Ore processing artisanal miners.

C- Artisanal miners.

D- Mining companies.

The Number of respondents of each category for all sites is summarized in Table (1) Characteristics can be seen in Appendix (3).

Table 1: Study Sites and Number of Respondents

State	Locality	Town/Village	No. of Respondents			
			communty	Artisanal Miners	Ore Processors	Companies
Gold-bearing	**Berber**	**Abydia**	34	22	19	1
Gadarif	**Butana**	**Al Subagh**	15	6	8	1
	Qala EnNahl	**Um Saqata**	25	18	14	1
Blue Nile	**Wad Elmahi**	**Belgawa**	20	22	16	1
Total			**94**	**68**	**57**	**4**

Additionally, a special checklist was prepared to collect data from government officials. Four enumerators were trained and engaged in data collection and interviewing of respondents.

2.3.2. Remote Sensing and GIS Investigations

The main objectives of the remote sensing and GIS investigations are to trace, delineate and evaluate the changes in the vegetation cover and the degradation of the flora in the mining areas for two time periods 1999 and 2019. The studies of the optical multispectral data provide spectral, spatial, and temporal information about the changes of the vegetation cover before and during the gold mining activities in Belgawa (Blue Nile State) and Um Saqata (Gedaref State)

The remote sensing data source is as follows:

1. Multispectral optical data of Landsat 7 ETM+ data
   I. LE07_L1TP, path 171, row 052, acquisition data 6 November 1999. Belgawa area.
   II. LE07_L1TP, path 171, row 052, acquisition data 11 January 2001. Belgawa area.
   III. LE07_L1TP, path 171, row 052, acquisition data 2 February 2003. Belgawa area.
   IV. LE07_L1TP, path 171, row 051, acquisition data 6 November 1999. Um Saqata area.
   V. LE07_L1TP, path 171, row 051, acquisition data 29 March 2000. Um Saqata area.
2. Multispectral optical data of Landsat 8 OLI + data
   VI. LC08_L1TP, path 171, row 052, acquisition data 21 November 2019. Belgawa area.
   VII. LC08_L1TP, path 171, row 052, acquisition data 9 February 2020. Belgawa area.
   VIII. LC08_L1TP, path 171, row 051, acquisition data 21 November 2019. Um Saqata area.

During the course of this study no geometric or geo-referenced correction was made for the images, since all images were all geometrically corrected and geo-referenced according to the UTM (Universal Transverse Mercator) system with the following parameters: (Projection: UTM, Grid Zone: 36 N, Spheroid: WGS 1984, Datum: WGS 1984, Unit: Meter).

The radiometric correction has been applied for images using the Atmospheric Correction method (ATCOR). ATCOR is a method used to reduce atmospheric and illumination effects on satellite image data to retrieve physical parameters of the earth's surface such as atmospheric conditions (emissivity, temperature), thermal and atmospheric radiance, and transmittance functions to simulate the simplified properties of a 3D atmosphere. The objective of this method is important for the analysis in order to remove or reduce the influence of atmospheric and solar illumination and be able to compare multi-temporal satellite images with different times of acquisition.

After the radiometric correction has been applied all images were spatially and spectral sub-setting to the extent of the selected areas of Belgawa and Um Saqata mining areas.

The main aim of the image enhancement is to render the images visually interpretable appearance so that the analyst will gain information from the images. In this respect, two False Color Composite (FCC) images were prepared for the selected area using simple linear stretching techniques with 2% trimming. The first FCC images are the vegetation images using the linear stretching 2% of the combination of NIR, Red, and Green bands in the R, G, and B color gun to reveal the spatial distribution of the vegetation cover in the selected area with red colors. The second FCC image was prepared by using the linear stretching 2% of the combination of SWIR2, NIR, and Blue bands in the R, G and B color gun to reveal the main geomorphological and geological aspects of the selected areas. However, vegetation cover is illustrated by green colors.

The Normalized Difference Vegetation Index (NDVI) is the main transformation process applied in the study. The NDVI is a numerical indicator that uses the visible red and near-infrared bands of the electromagnetic spectrum. The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements, often from a space platform, assessing whether the target being observed contains live green vegetation.

2.3.3. Water and Soil Samples

Fourteen soil and water samples were collected to detect pollution. Soil samples were collected from the top 20 cm while water samples were collected from boreholes, hafeers, and the Gold-bearing. Control samples, away from the mining area were also collected for comparison.

These samples were analyzed using ICP (Induced Coupled Plasma) at the National Forensic Laboratories in Khartoum for Cadmium, Lead, Nickel, and Mercury.

2.3.4. Observations and Impressions

The team documented his own observations and impressions through side discussions to verify findings. This was also supported by videos and photographs of different mining processes and reclamation experiences.

2.3.5. Data Processing

The data collected was coded and analyzed using SPSS. The data is depicted in tables and figures.

Chapter 3: Mining in Sudan

3.1. Introduction

Non-hydrocarbon minerals of actual or potential commercial value in Sudan include gold, chrome, copper, lead, iron, manganese, asbestos, gypsum, mica, limestone, and marble. Gold had been mined in the Red Sea Hills at Gebeit, Ariab, and several other mines near the Red Sea since ancient times. In the last few years, there is an outburst rush in gold mining both modern and traditional.

Chrome ore was mined in the Ingessana Hills in Blue Nile State. Large gypsum deposits were found along the Red Sea coast. Limestone, found in substantial quantities in Sudan, was mined for use in making cement and other construction materials. Marble was also quarried as a decorative stone. There has been some commercial mining of mica, exploitable deposits of which had been found in Northern state. Manganese and iron ore of which several large deposits exist in different parts of the country have been mined at times but only on a small scale.

All these mining activities remove thousands of square kilometers of vegetation mainly forests, rangeland, and soils, interrupted ecosystem service flows, and resulted in an inevitable and often permanent viable land loss. Mining activities also frequently result in toxic waste that causes water pollution which affects both fauna and flora with all the attendant health problems.

The rush of Artisanal gold mining in Sudan (1998–2015), encourages the investors to explore gold and other industrial minerals. The discovery of gold and base metal sulfides in Ariab district in the Red Sea Hills, eastern Sudan, during the last century, attracted the attention of geologists as well as international mining investment companies. There are more than 245 sites of gold mining distributed geographically in almost all Sudan States (Fig.2). The gold production of artisanal mining amounts to 85% of the total gold production in Sudan.

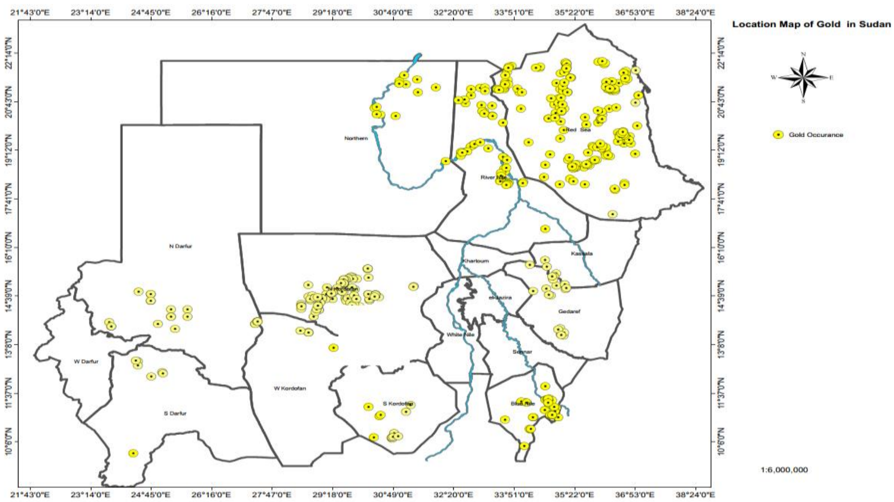


Figure 2: Gold Mine Sites in Sudan

Artisanal gold mining in Sudan has contributed enormously to the rural development and raise the individual income. It offers job opportunity to many people especially those in the marginal areas of the country; however, these benefits are not distributed evenly (Table 2).

Table 2: Number of artisanal gold mining sites in Sudan (SMRC, 2017)

No.	State	No. of Artisanal Gold Mining Sites
1	Northern	42
2	Gold-bearing	32
3	Red Sea	24
4	Kassala	8
5	Gadarif	18
6	Blue Nile	11
7	North Kordofan	19
8	South Kordofan	39
9	West Kordofan	13
10	North Darfur	9
11	West Darfur	6
12	Middle Darfur	16
13	South Darfur	6

(Source SMRC Report 2017)

3.2. The Mining Process

After geological mapping, prospecting, exploration stages, and feasibility studies; mining generally commence either surface or underground or both. Surface mining development usually starts with the removal of the soil and rock overlying the deposits. Detrital and unconsolidated materials are excavated with the use of scrapers, bulldozers or digging machines. Rocks and solid ores are drilled and blasted before mining ore. Underground gold mining is used to extract ore from below the surface of the earth safely with minimum waste materials. Ore minerals are crushed and milled, stored, and dressed in various ways including physical and chemical methods. All these operations and effects lead to changes in the earth's surface as well as underground. Gold mining by artisanal miners usually comprises the following steps:

a) Extraction: Miners exploit alluvial deposits (river sediments) or hard rock deposits. Sediments or overburden is removed, and the ore is mined by surface excavation, tunneling, or by dredging in the case of alluvial mining.

b) Processing: In this step, the gold is liberated from other gangue minerals. The methods used for processing can vary depending upon the type of deposit. Gold particles in alluvial deposits are often already separated and require little mechanical treatment, while for hard rock ores, crushing and milling are required. Primary crushing can be done manually, for example using hammers, or with machines. Mills are then used to grind the ore into smaller particles and, eventually, fine powder.

c) Concentration: In some cases, gold is further separated from other materials by concentration. Different methods and technologies (e.g. water panning, sluices, centrifuges, vibrating tables, etc.) may be used to concentrate the liberated gold. The density of gold is higher than the associated materials, therefore many techniques utilize gravity.

d) Amalgamation: Elemental mercury is used to obtain a mercury-gold alloy called an "amalgam". There are two main methods used whole ore amalgamation and concentrate amalgamation.

Sudanese artisanal miners normally use water panning with mercury if the gold ore is ground by air mill, while in extraction using water wheel mill the process of extraction by mercury is done simultaneously with the grinding. As a result of this process, part of mercury is released as waste into the mine tailings because of the inefficiency of this process (WHO, (2016)). Some the mercury can also be recovered and could be recycled.

e) Burning: The amalgam is heated to vaporize the mercury and separate the gold. In "open burning". All of the mercury vapor is emitted into the air and the gold produced by amalgam burning is porous and is referred to as "sponge gold.

f) Refining: Sponge gold is further heated to remove residual mercury and other impurities. Throughout this process, miners as well as other living and working nearby to the processing sites are exposed to a variety of environmental and occupational health hazards.

3.3. Institutional Setup of the Mining Sector

The Ministry of Energy and Mining is the responsible Government authority for the mining sector in Sudan. The mining authority within the Ministry consists of four main institutions: Geological Research Authority of Sudan (GRAS), Sudanese Mineral Resources Company (SMRC), Sudamin, and Ariab Gold Mining Company.

3.3.1. Geological Research Authority of Sudan (GRAS)

The Geological Research Authority of Sudan (GRAS) is responsible for the overall promotion of the mining sector. It assigns concession blocks and negotiates agreements with investors on behalf of the Ministry of Energy and Mining. The agreements which cover both exploration and exploitation periods are based on the Mineral Development Act (2015) and Regulations. Investors are entitled to privileges and provisions of the Investment Encouragement Act (2013) and Amendments, and the recently approved Sudan Mining Code (SMC) (2017) which provides guidance for reporting on exploration results, mineral resources, or reserves and mining activities.

3.3.2. The Sudanese Mineral Resources Company (SMRC)

The SMRC is the regulating branch under the Ministry of Energy and Mining responsible for monitoring, controlling, and regulating the financial and environmental obligations of mining operations. Accordingly, it has established a specialized directorate under the name of the General Directorate for Health, Safety, and Environment (HSE), and Community Social Responsibility (CSR). This directorate is guided by the Requirements and Guidelines document approved in March 2017. The directives provide the legal and guidance framework that enable the Sudanese mining organizations to know their responsibilities, develop adequate management systems, comply and be held a countable for noncompliance violations. These directives govern all organizations and companies involved in any form of mining, weather actual mining of rocks and minerals, mineral processing, mine waste management, or supply of material and other support services. The SMRC is, therefore, fully responsible for the compliance of companies and individuals with environmental conservation issues. Companies should submit Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP).

3.3.3. Sudamin

Sudamin Company was established in 2012 as a joint venture between the Ministry of Finance (99%) and the Central Bank of Sudan (1%) with the aim of promoting and strengthening the mining sector. The company provides mining services through participation in commercial and investment in gold mining as a strategic economic sector in Sudan. The company provides services that the private sector can't avail such as mineral exploration and mining field developments for all minerals whether inland or deep waters. The Company is also mandated to reclaim artisanal mining sites based on approval from relevant authorities. It establishes laboratories for analysis and quality control. Sudamin is authorized to import all equipment used by the mining sector and act as an official agent for international mining companies.

3.3.4. Ariab Mining Company

Ariab Mining Company is the biggest gold mining company in the country. It was established in 1991 as a joint venture between the Government of Sudan and the BRGM (French company) for gold exploration. Recently, the company became fully owned by the Government of Sudan. Ariab Company is working in Ariab district, Red Sea State in eastern Sudan and it has the biggest known gold, copper and silver reserves. In the year 2001 Ariab Company produced 6 tons of gold.

3.4. Types of Gold Mining Licensing

There are two types of gold mining in Sudan; Legal mining which includes large and small scale mining and artisanal (Traditional) mining (Ministry of Energy and Mining, 2017).

3.4.1. Legal Gold Mining

There are four kinds of licensing for legal gold mining:

i) General prospecting license

It is the license that guarantees the holder the right to enter the area covered by the license for sampling other than the area allocated for exclusive prospecting license or an area in respect of which a mining contract is concluded. Priority is given to the first applicant (First Come First Win). The license is given upon payment of the prescribed fees, provision of a certificate of incorporation, provision of the audited accounts for the immediately preceding year and evidence of technical and financial resources available to the applicant together with tax clearance and company profile.

ii) **Exclusive Prospecting License**

It means the license issued under the Act and guarantees the holder the right for exploration in the area covered by the license, including geological, geochemical and geophysical activities, exploratory drilling work and taking samples for the necessary analysis and ascertain the technical and economic viability of the mineral deposits.

The main requirements for an exclusive prospecting license include; holding of valid general prospecting license, proof of previous experience, evidence of technical and financial resources, work plan, expenditure commitment, baseline study and environmental impact assessment describing the details of any significant adverse effects that the program is likely to have on the environment or any archeological or heritage sites together with an estimated cost of remedying such adverse effects.

iii) Mining lease

It is issued under the Mineral Resources Development and Mining Act (2015) and guarantees the holder the right to recover, extract, and exploit mineral materials by all necessary scientific, technical and technological means and disposes thereof in accordance with the provision of the Act and regulations issued thereof.

iv) Artisanal (Traditional Mining) permits

Artisanal mining licenses shall confer on their holders the right to prospect for and mine the substances for which they have been issued within the boundaries of their perimeter and up to 30m in cases of step room mining activities and 10m in cases of excavation mining operations (Ministry of Energy and Mining, 2017). However, such licenses shall not allow mining using tunnels. The artisanal miners can at any time request the conversion of their titles into small-scale mining licenses provided they have the necessary financial and technical resources. The mining license shall cover an area that has the shape of a polygon with sides not exceeding 100m unless otherwise authorized.

3.4.1.1. Shortcomings in the Current Licensing System

The procedure of licensing doesn't require that the Ministry of Energy and Mining coordinate with any other governmental authority. However, before they give the license, they consult the State Government to make sure there are no disputes in the target area. The State should coordinate and ensure the agreement of related institutions such as the Ministry of Agriculture, the Rangeland Administration, Forestry, Tourism and Archeology, and the local community regarding the proposed land use.

The law governing land ownership between the Federal Government and the State Government is not very clear to resolve disputes between stakeholders.

The main drawback in this system is the isolation of the related institutions at the federal level from the decision-making process and hence, it opens the door for corruption at the state level. This could be resolved by the following:

1- Potential areas for mining should be delineated by the State authority within the approved investment map of the state.

2- The environmental and social impact assessment provided by mining companies should be subject to scrutiny and approval by the Higher Council for Environment and Natural Resources.

3- Adherence to the approved Environmental and Social Impact Assessment (ESIA) should be properly monitored by the Sudanese Mineral Resources Company (SMRC).

3.4.2. Artisanal Gold Mining (Illegal Mining)

Artisanal gold mining refers to mining by individuals or groups of people or families with minimal or no mechanization, often informally and/or illegally. The Minerals Wealth Development and Mining Act (2015) defines traditional artisanal mining as an activity practiced utilizing local traditional means. It is practiced all over the world in the production of precious metals such as gold, diamond, tantalum, and gemstones as well as other industrial minerals and building materials.

In Sudan, it is believed that more than 2 million people have practiced gold mining since 1998 up to now with over 4 million dependents directly benefitting from these activities. Other sources claim that gold mining provides employment and livelihood for around 5.3 million persons, directly benefiting from this sector, bringing the total persons directly depending on the artisan mining to about 14% of the total population. This percentage does not include those who are indirectly benefiting from the sector. Given a labor force of about 12 million persons, the artisanal gold miners constitute around 8% of the total labor force (GEO Services International, 2015).

The most important drawbacks of artisanal gold mining could be summarized as follows:

- Gold mining by its nature is destructive to the environment. In Sudan, it has negatively affected forests, rangeland, wildlife, agriculture, and polluted water, soil, and air.
- Obliteration of the geological environment so that it becomes hard and/or impossible to be prospected, explored, or mined by professional companies.
- The pollution of the environment by chemicals such as Mercury affect human, animal and plant health.
- Create significant demographic changes.

3.4.1.1. Best Practices in Artisanal Mining

Governments around the world have taken different approaches to work with artisanal miners and managing the artisanal mining sector. Several countries have introduced policy measures trying to legalize and formalize artisanal mining with varying results (Singo and Seguin, 2018).

Recently, documented best practices of formalization from three countries – Colombia, the Democratic Republic of Congo, and Mongolia are reported by Singo & Seguin (2018). The artisanal mining sector can be susceptible to conflict financing and corruption with artisanal miners having limited options for protection when targeted by arm groups or corrupt actors. Formalization can lead to greater transparency, making it easier to identify illicit actors. Formalization includes:

i) Create conducive and appropriate legal and policy frameworks.

ii) Provide legal access to minerals for the artisanal and small-scale mining sector including designated specific areas.

iii) Adopt a flexible approach allowing miners to create dynamic associations tailored to their realities.

iv) Mainstream artisanal into the country economic program.

v) Provide artisanal miners with geological information for more efficient mining.

vi) Provide access to capital and equipment and technical assistance.

vii) Provide access to formal minerals markets.

viii) Establish clear institutional mandates and decentralize roles with local and regional governments so that services can be brought directly to miners.

ix) Create space for participation and engagement of different stakeholders in drawback, paying special attention to vulnerable and marginalized groups, such as women and the indigenous population.

Prohibition and criminalization were not effective and failed to make meaningful progress in managing the sector. Formalization should start with proper policies and legislation.

3.5. Safety and Environmental Monitoring in the Gold Mining Sector

The Health Safety and Environment Management System (HSEMS) in the Gold Mining Sector is the sole responsibility of the Sudanese Mineral Resources Company (SMRC). According to the Requirements and Guidelines Document, the Health Safety and Environment Management System (SMRC, 2017), aims to:

i. Prevent or reduce incidents, injuries, occupational illnesses, pollution, and damage to assets.

ii. Raise the awareness of both employers and employees of the HSE issues.

iii. Comply with national and international HSE guidelines, standards, and laws.

iv. Contribute to the national efforts for achieving sustainable development.

HSE should respect the principles of internationally established human rights standards such as the international convention on human rights and gives special attention to the rights of vulnerable social groups such as women, disabled persons, and minorities. In principle, the organization shall confirm that the business meets the requirements for environmental and social consideration. The organization should also confirm that the various stages don't deviate significantly from the World Bank's safeguard policies and refer as a benchmark to the international standards, treaties, and declarations; etc… and to the good practices of the developed world. The detailed conventions and treaties could be referred to in the HSE Requirements and Guidelines (SMRC, 2017).

As an environmental management process, the organization shall continually strive to minimize the impact of its operations on the environment. Plans shall be developed, and appropriate actions are taken to prevent environmental pollution, conserve resources and minimize waste. Where elimination of pollution sources is not practical, appropriate treatment of waste shall be undertaken to minimize its impact on the environment. It is also required to carry out an environmental and social impact assessment on all major activities and expansions. Provided that an ESIA study has not been conducted prior to the commencement of business activities, an environmental review shall be performed.

All organizations shall incorporate the output of environmental and social impact studies in project planning as a tool for the decision-making process throughout the project life cycle.

Noncompliance with SMRC or violation of requirements gives SMRC the right to take administrative or legal actions that were deemed necessary. To monitor and enforce the regulations, SMRC appoints a resident staff in each company who reports to his company on regular basis. In addition to that SMRC conducts regular and surprise visits to mining companies. In many cases, non-compliance incidents of companies are dealt with seriously while sometimes amicable procedures are followed. The design of the monitoring system looks comprehensive while application on the ground has some limitations and loopholes which might open doors for corruption. This implies that there are some gaps or weaknesses of related policies and monitoring systems. This monitoring system is only limited to the legal mining sector.

Isolation of local communities from discussions and decision-making processes of approval of mining sites is an important social and environmental weakness in the approval and monitoring processes. Environmental and/or negative impacts of mining operations, perceived or proven by the community, create disputes and in many cases lead to injuries, and death among both community and company staff. The damage of companies' properties caused by the local communities in South Kordofan, Butana, and Northern state are typical examples. Disputes are not uncommon between small and big companies, small companies, and communities, and artisanal miners and companies.

While legal and regulated mining is governed by policies and laws as described above, artisanal mining is totally uncontrolled. Artisanal miners are characterized by high mobility, abundance (over 2 million), mostly ignorant or with little education, and coming from poor backgrounds. These characteristics render them very difficult to be managed or controlled and in general they have very poor sense of the environment. Attempts to regulate their activities have failed or gave very limited success. In most cases, the local government represented by the locality is interested in collecting taxes and revenue from artisanal miners with limited services in return. One good practice by localities is confining the processing plants and markets in certain designated places which reduces the adverse impact of chemical and air pollution. However, the environment in these markets and the surrounding areas are very unhealthy and conducive to the spread of diseases. There are no proper dumping sites, no sanitary facilities and shortage in water for drinking and other uses. The markets also lack health facilities. The artisanal miners usually depend on health facilities in the nearby villages creating more pressure on the already week services and may transmit diseases that were not known to the area.

It is very clear that the local authorities provide no services or protection to the health and safety of the artisanal miners, let alone the environment. Generally, the environment and environmental protection issues are of very low or no priority for both local authorities and the artisanal miners. If not addressed, the current and the expected impact of artisanal mining can be devastating.

3.6. Contribution of Mining to the National Economy

The contribution of the mining sector in the GDP according to the Central Bureau of Statistics and the Central Bank of Sudan (CBS) is ranging from 0.3% (2010) to its peak of 2.3% (2015) to 1.8% in 2018. Calculations of GDP were based on prices of goods including gold in 1981/82 which, if adjusted to current prices will show the real contribution to the GDP (Table3). The Table clearly indicates fluctuations between years. The Geological Research Authority of Sudan (GRAS) claims that the contribution of gold alone can be as high as 37%as in 2019.

Table 3: Share of Mining in GDP

Year	2010	2011	2012	2013	2014	2015	2016*	2017*	2018*
GDP in million SDG	29.4	27	27.3	28.4	29.1	30.3	34.7	35.9	37.9
Mining Sector in million SDG	0.1	0.4	0.15	0.21	0.23	0.7	0.6	0.69	0.7
Mining Sector share in GDP	0.3%	0.2%	0.5%	0.7%	0.8%	2.3%	1.7%	1.9%	1.8%

*Source: Central Bureau of Statistics and the Central Bank of Sudan Annual Reports. *Preliminary estimates.*

Gold is partially responsible for the growth in other related sectors such as transport, building, and construction, trade, and hotels. Most of the positive impacts of artisanal gold mining are often within the informal sector which is mostly uncaptured by the official statistics. However, benefits are not evenly distributed.

The National Government does not impose any taxes on artisanal gold mining. However, localities are benefiting not only from taxes from artisanal mining but also from the other local taxes imposed on the small businesses created by the gold mining sector. It is worth mentioning that the localities contribute very little to the development of services for the communities or to improve the working conditions of artisanal miners.

The Central Bank of Sudan is the only body allowed to export gold. It pays the actual market price for gold exports at the parallel exchange rate and bears the exchange rate difference. Gold and other minerals exports increased the supply of foreign exchange and greatly helped in stopping the further deterioration of the local currency versus the foreign currency (Table 4). The most important minerals contributing to exports in Sudan are gold and chromite with maximum exports reported in 2017.

Table 4:Exports of Minerals Value in US$ million

Mineral/ Year	2012	2013	2014	2015	2016	2017	2018	2019
Gold	2,158	1,048	1,271	726	1044	1,559	832	1,221
Chromite	3.4	3.5	11.3	3.0	5.2	2.6	2.0	2.5
Other minerals	0	0	5.9	0.1	0.2	1.1	0.8	0.7
Total	2,161.4	1,051.9	1,288.5	728.7	1,049.2	1,562.2	835.0	1,223.9

Source: Foreign Trade Statistical Digest. Central Bank of Sudan

The discrepancy in the contribution of the mining sector in GDP, including gold could be attributed to:

i) There a is clear inconsistency in information from the different official sources.

ii) Instability in policies related to gold exports.

Iii) Artisanal mining sector is not governed by clear policies and regulations.

iii) Large amounts of gold produced by artisanal miners were not accounted for in exports due to smuggling and the use of unofficial channels.

iv) Fluctuation in production for different reasons e.g. lack of fuel, finance, etc.

Gold smuggling continues to curtail the benefits from the gold production and Sudan would not benefit fully from gold mining as a source of hard currency if smuggling continued. The discrepancies between the production figures of gold and the export figures clearly indicate massive smuggling (Table 5). This was clearly admitted by the Ministry of Mining and confirmed by the reports of the Customs Administration.

Table 5:Gold Production and Exports

Years /Quantity	2012	2013	2014	2015	2016	2017	2018	2019
Production KG	40,000	70,000	73,300	82,300	93,400	107,300	93,600	-
Export KG	46,133	24,813	30,445	19.389	26,973	37,518	20,176	21,756

Source: Foreign Trade Statistical Digest. Central Bank of Sudan

More than 135 large-scale concessions (300 Km^2) and 160 large-scale concessions (1-5Km^2) agreements for exploration and exploitation of gold have been signed between the government of Sudan and national and international mining companies (Fig.3). There are 77 gold tailing processing companies out of which 57 are productive; most of them are in the Gold-bearing state. Some of these companies are in different stages of exploration and evaluation and had declared commercial discoveries. Some companies are already producing gold such as Ariab, Rida, and Managem. This depicts that the gold mining sector in Sudan has a huge contribution to the national economy and livelihood in terms of income and employment.

The government owns between 17% to 56% of shares and is entitled to a royalty of 7% from the gross production of gold. Business Profit tax is 15%, Zakat 2.5%, and 2% for the Community Social Responsibility (CSR). The total production of pure gold in 2017 reached 117 tons, around 85% of which was produced by artisanal mining. Sudan ranked third in gold production after South Africa and Ghana among African countries.

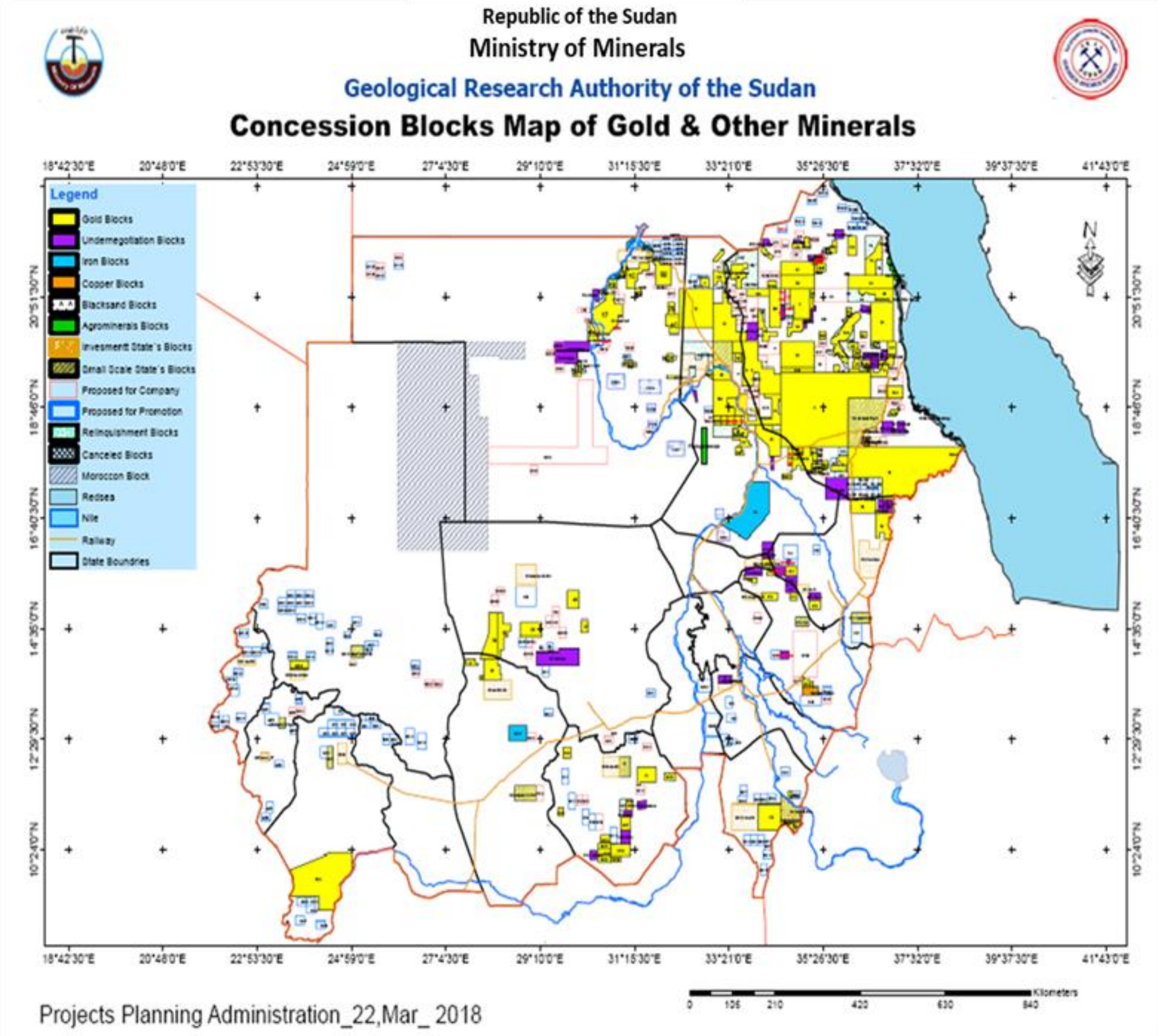


Figure 3: Concession Blocks map of gold and other minerals in Sudan

Chapter 4: Impact of Mining on Natural Resources

4.1. Introduction:

Mining is known globally as one of the drivers for deforestation and natural resource degradation. A study by Sonter et al., (2017) shows loss of Amazon forest of about 11,670km^2 area deforestation between the years 2005 to 2015 where 9% of the loss is contributed by mining leases. A sharp increase in mineral prices can result in a surge in mining activity, which contributes to deforestation in some locations. A study by the University of Puerto Rico found that tree cover loss in the Madre de Dios region of Peru has increased significantly since 2007 as a result of artisanal gold mining (Alvarez-Berríos & Aide, 2015). Mining is a lucrative activity promoting development booms that may attract population growth with consequent deforestation. The deforestation rate due to mining activities in Guyana from 2000 to 2008 increased 2.77 times according to an assessment by the World Wildlife Fund-Guianas. Similarly, in the Philippines, mining, along with logging, has been among the forces behind the country's loss of forest cover from 17 million hectares in 1934 to just three million in 2003, or an 82 percent decline (Docena, 2010).

In Sudan negative impact of mining on the forest was reported by Khalil et., al (2005) in Belgawa in the Blue Nile State. Deforestation and desertification were caused by salt mining in Al Ga'a area in northern Kordofan state due to the abuse of firewood. Similar effects were reported in the artisanal production of lime near widely distributed marble occurrences in Nuba Mountains in South Kordofan state and near J. Dumbair in North Kordofan state, and Ingessena hills in the Blue Nile State.

In general, the current status of natural resources in Sudan is one of continuous land degradation and the root causes include armed conflict, lack of effective planning and the implementation thereof, uncontrolled expansion of agriculture into forests, rangeland and wildlife areas, uncontrolled fires in natural rangelands and forests, overgrazing, imprudent use of natural resources, poaching, overfishing, and the adverse impacts of the petroleum industry, artisanal mining and the sugar industry on natural habitats.

Besides, Sudan is lacking a comprehensive policy and legislative framework that deals with land use in an integrated way (Atta Elmoula 1985, Tolentino (1994). Rather, there are a number of individual sectoral policies e.g. agriculture, forestry, wildlife, energy, and other resources. Below is a summary of existing policies on Forest, Wildlife and Rangeland.

Recently in Sudan, the REDD+ Program provided financial and technical support to many studies, the most important of which are the In-depth analysis of Drivers of Deforestation & Forest/Range Degradation (DoDD) and the Strategic Environmental and Social Assessment (SESA).

The main objective of the In-depth analysis of Drivers of Deforestation & Forest/Range Degradation study was analyzing and evaluating the impact of key drivers of deforestation and forest degradation in the Sudanese basis for conservation interventions and feasibility of REDD-plus in the Sudan (Hassan and Taj Consultants, 2018). The study identified six key drivers, namely, Commercial Agriculture principally large-scale, mechanized rainfed farming, together with irrigated forms of agriculture, urban sprawl, infrastructure development, petroleum exploration, mining, and refugees and internally displaced people. The rating of the impact of these drivers is based on severity, aerial extent, and duration needed to restore forests/vegetation to their original state. While the first four drivers were analyzed in-depth, the mining sector was not, which triggered this study.

This part of the study discusses in more detail the impact of mining activities on natural resources, specifically on forests, rangeland wildlife soil, and water resources. The impact of mining on human health was briefly discussed.

4.2. Impact of Mining on Forests

The first national forest policy in Sudan was declared in 1932. The main objective of that policy was the protection and establishment of forests together with the development of their resources in order to sustain their protective, environmental and productive role so as to meet the population needs in terms of forests products.

The Comprehensive National Strategies (CNS 1992 – 2002 and 2003 - 2027) are both concerned with the importance of forestry in environmental conservation and as a source of goods and services for the country, and local communities. The CNS supported an increase in forest cover, range and nature reserves to an area equivalent to 25% of Sudan's area. Since 1992, Sudan has also put in place several strategies, policies and programs aimed at sustainable development.

The proposed policy of 2006 defined as the Sudan National Forest Policy Statement, is a recent update of Sudan's Forestry Policy 1986. The 2006 Statement, which has not yet been ratified, incorporates poverty reduction strategy, improvement of people standards, amelioration of physical environment, and combating desertification.

It can be concluded that the conservation and enhancement of the forest cover is a priority of the Government of Sudan as stated in the constitution and Forest & Environmental policies where FNC & related other institutions are obliged to work and achieve tree cover of 20% percent of the country area by 2027.

Analyzing the forest policy and other related policies, it can be seen that there is a clear gap dealing with mining as one of the sources of damage to natural resources, in particular in vegetation cover. This could be attributed to the fact that gold mining outburst is a fairly recent activity in Sudan and therefore, these policies didn't include stipulations dealing with regulating mining activities in designated forests and rangeland areas. Moreover, they didn't include guidance on the reclamation of related degraded sites. These gaps in forest policies and enforcement of associated laws are reflected in the observed damage to forest and natural resources and retreat of the vegetation cover in mining sites.

This study reveals that there is evident destruction due to gold mining activities in all surveyed sites. Table (6) shows that the communities are of the opinion that mining is very destructive to forest resources. Deforestation and reduction of tree density are the main features of the impact of mining. Miners use forest resources as a source of energy while unemployed artisanal miners are engaged in charcoal making and firewood collection. A considerable amount of wood is collected for supporting underground mines and for building temporary huts. However, artisanal miners, ore processors and gold companies, out of denial or ignorance, think that mining has no or minimal effect on forest resources. Figure (4) indicates that miners are dwelling inside the forests or living nearby causing direct degradation of the forest resources and in most cases is less than one kilometer which makes them subject to damage by miners.

Table 6: Impact of Mining on Forest

Impact on forest	Percentage of Respondents			
	Community	Artisanal	Ore Processors	Companies
Deforestation	80%	6%	4%	-
Reduced tree density	17%	32%	26%	25%
Tree death	2%	3%	3%	-
Has no negative effect on forest	1%	59%	67%	75%
Total	100%	100%	100%	100%

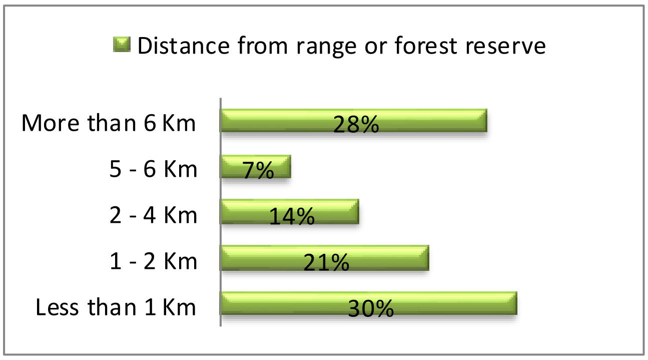


Figure 4: Distance of Mining sites from Forest and Range Areas:

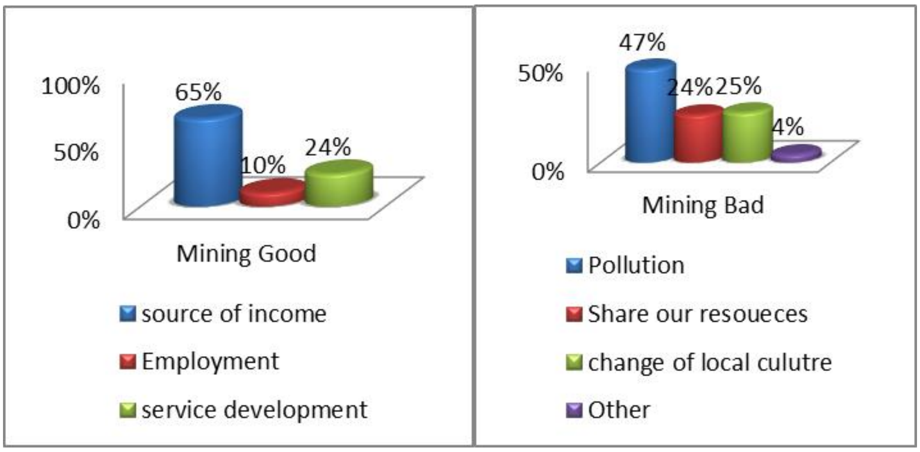


Figure 5: Community perception on mining

Despite that communities feel the destructive and bad effects of mining activities such as pollution, the share of resources by others, and change of culture due to influx of different ethnicities; they still see it as an opportunity for better livelihoods as a source of income, employment and services development (Fig 5). This appraisal of mining activities on the part of communities may reduce their inherited commitment to the protection of natural resources in their vicinity. Dedicated awareness programs are needed to strengthen the role of communities in the protection of natural resources especially forests and rangelands in mining areas.

Respondents in Abydia area argue that there is no differentiated impact of mining activities on women and children, except that men may get directly involved in mining processes and therefore, be away from families for long times. On the other hand, women and children benefit from a direct increase in income and improvement of the socio-economic status of the family. While in Belgawa women and children are directly engaged in mining

Communities in Belgawa area, indicate that species such as Talih (A*cacia seyal)* and Sahab (*Anogeissus leiocarpus)*, Habeel (*Combretum hartmanianum),* Ebony (*Diospyros spp*) and Hashab (*Acacia senegal*) have disappeared or are rarely seen around the mining sites.

Forest Management in the three states visited confirmed that the forests are impacted by mining activities. For example, in Gadarif State there are wood chopping, charcoal making, and lodging practiced in reserved forests by miners. Clear and partial felling is evident, however, in Butana Locality there are some reclamation attempts of some of the degraded lands by using mining pits as water catchment to plant trees. Species planted are mainly *Acacia seyal* (Talih), *Acacia nilotica (*Sunut*), Ziziphus spina Christi* (Sider), and *Acacia millifra* (Kittir). These good practices are made possible through the IFAD-funded Butana Integrated Rural Development Project (Photos 1&2). The project was started (2009) and succeeded to cultivate 23,513 feddans of trees in the mining pits. Moreover, the Forest Management in Gadarif managed to plant 10% of the degraded land through special funds and there is a plan for planting 15,000 feddans annually.

In the Blue Nile State, mining is also practiced in reserved forests where 1100 feddans were severely affected. Species such as *Acacia seyal* (Talih), *Combretum hartmanianum* (Habeel), *Anogeissus leiocarpus* (Sahab), are affected more than others. Conflict between the State and National Forest Authority seems to be a major obstacle for the protection of forest reserves. In the Gold-bearing state the forests are less affect by mining activities, however, species such as *Acacia tortilis* (Samor) and *Prosopis species* are affected. Regular annual reforestation in the state is about 3,000 feddans and there are some investments for rehabilitation using Taungia system, especially along Atbara River. Compared to the two other sites, the vegetation cover is scarce and more fragile as the area lies in the semi desert zone.

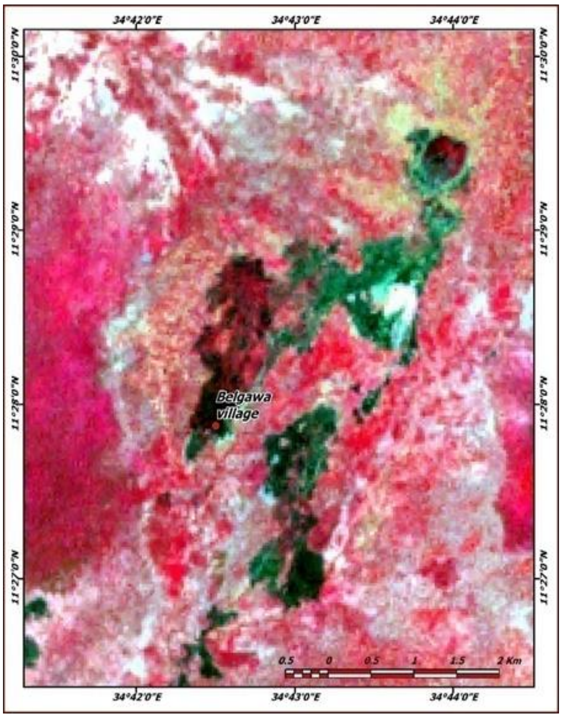
Photo (1) **Photo (2)**

Cultivation of trees in artisanal gold mining pits, executed by IFAD near Al Subagh village, Butana region.

A remote sensing technique has been applied to detect the change in vegetation cover in Belgawa (Blue Nile State) and Um Saqata (Gedaref State). This change can't be seen in Abydia and Butana regions which are inherently low in vegetation.

In Belgawa mining area, a comparison between remote sensing imageries taken for (1999) at an early stage of mining, and the present (2019) depicts the huge change in the vegetation cover which is fanning out from the mining zone (Figs. 6–13). It was calculated that the degraded area around Belgawa site in Blue Nile State was severely impacted. From 10,000 feddans understudy,about 310 feddans were completely cleared (Red color area), while about 4170 feddans were slightly decreased in vegetation (brown color) (Fig.14). Inaccessible areas and the surrounding nearby areas of Blue Nile valley show an increase in vegetation cover probably due to the increase of water volume after the rehabilitation of Russeries Dam (2013).

In addition, artisanal mining may cause an indirect impact on forests due to i) related infrastructure development such as roads which could lead to exploitation of forests for commercial firewood and charcoal production) high population influx in previously inaccessible areas imposing high pressure on natural resources iii) increased hunting and poaching of wildlife, including by amateur foreigners iv) conflicts over land use between landowners and miners documented by the frequently reported incidents in most mining sites.



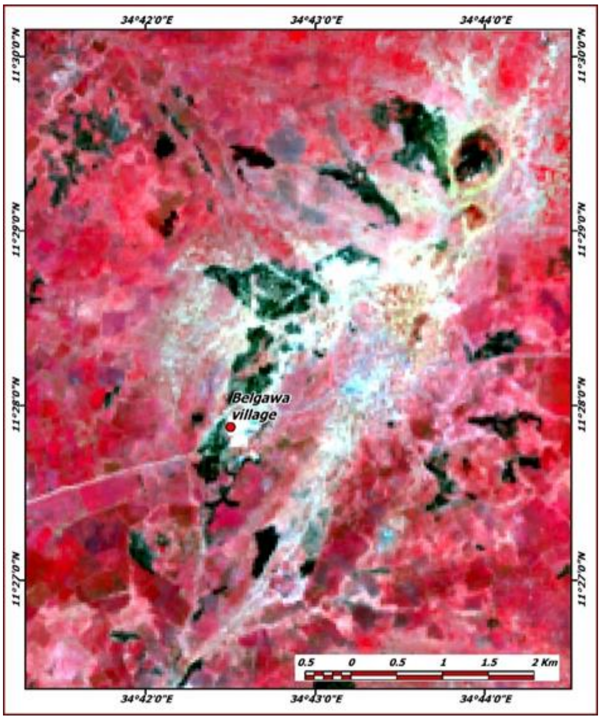


Fig (6) Fig (7)

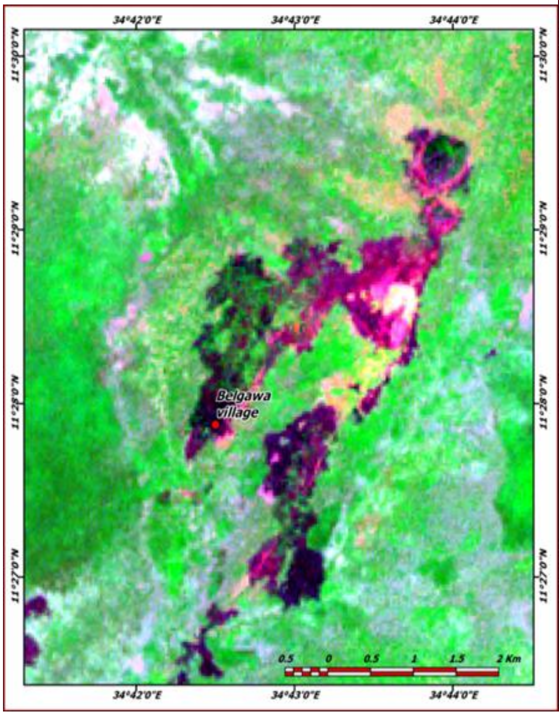
Figure 6: FCC False Color Composite image,6 November 1999, Belgawa

(FCC False Color Composite image of Landsat 7 ETM+ data obtained by 2% linear stretching of bands 4, 3 and 2 in the R, G & B (Landsat .7ETM+, path 171, row 52, acquisition date 6 November 1999)

Figure 7: FCC False Color Composite image,21 November 2019, Belgawa

(FCC False Color Composite image of Landsat 8 OLI data obtained by 2% linear stretching of bands 5, 4 and 3 in the R, G & B (Landsat 8 OLI, path 171, row 52, acquisition date 21 November 2019).

.



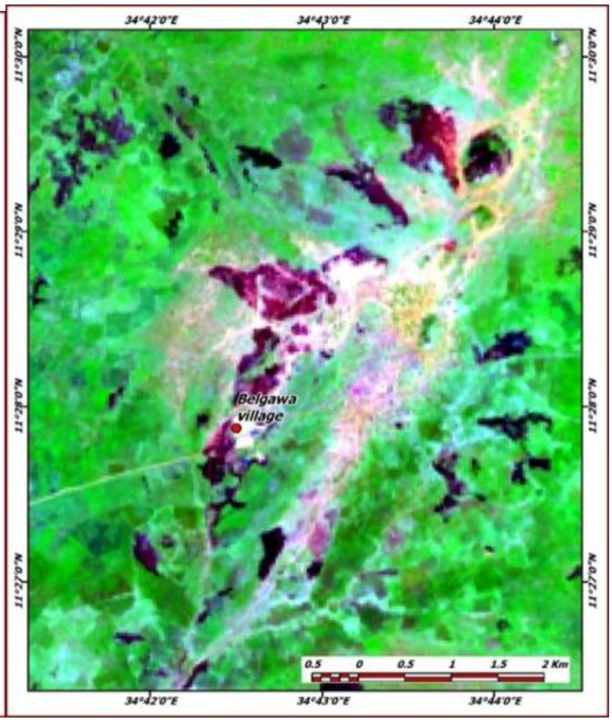


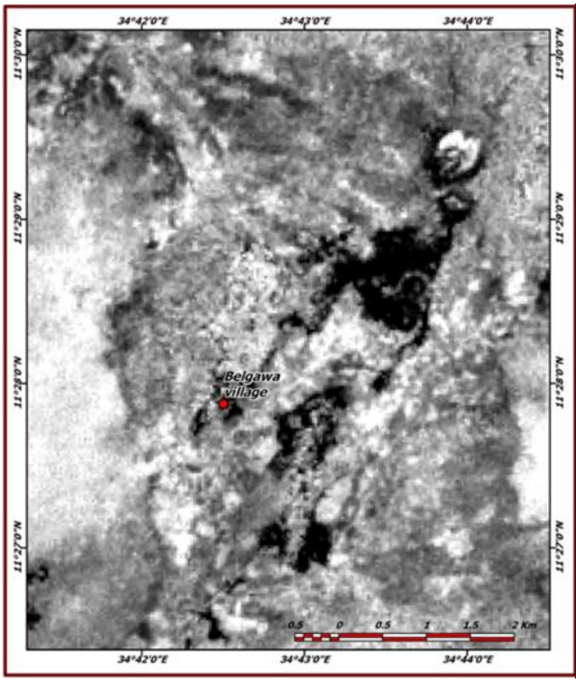
Fig (8) Fig (9)

Figure 8: FCC False Color Composite image, 6 November 1999, Belgawa

(FCC False Color Composite image of Landsat 7 ETM+ data obtained by 2% linear stretching of bands 7, 4 and 1 in the R, G & B (Landsat 7 ETM+, .path 171, row 52, acquisition date 6 November 1999)

Figure 9: FCC False Color Composite image, 21 November 2019, Belgawa

(FCC False Color Composite image of Landsat 8 OLI data obtained by 2% linear stretching of bands 7, 4 and 12 in the R, G & B (Landsat 8 OLI, path 171, row 52, acquisition date 21 November 2019.0)



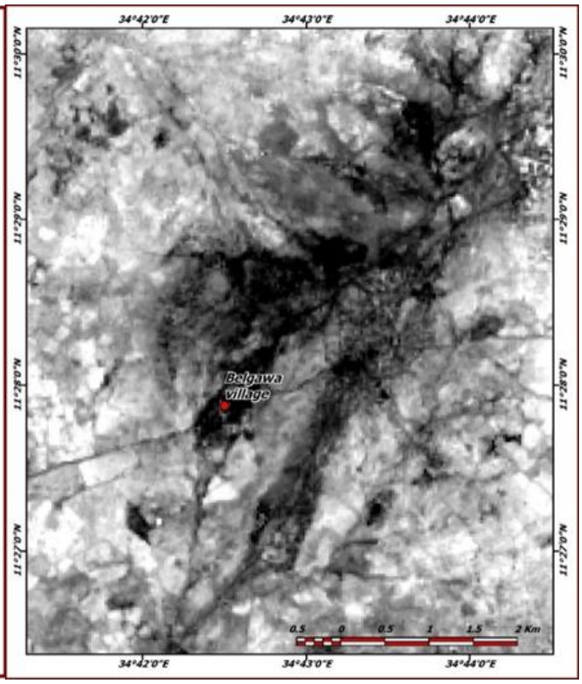


Fig (10)

Fig (11)

Figure 10: NDVI gray scale image, 6 Nov. 1999, Belgawa

(NDVI gray scale image obtained from Landsat 7 ETM+ data, path 171, row 52, acquisition (6 Nov. 1999. Bright and light colors indicate health .and dense vegetation while dark and black indicate light and poor vegetation cover)

Figure 11: NDVI gray scale image,6 Nov. 1999, Belgawa

(Figure 10:NDVI gray scale image obtained from Landsat 7 ETM+ data, path 171, row 52, acquisition (6 Nov. 1999. Bright and light colors indicate .health and dense vegetation while dark and black indicate light and poor vegetation cover)

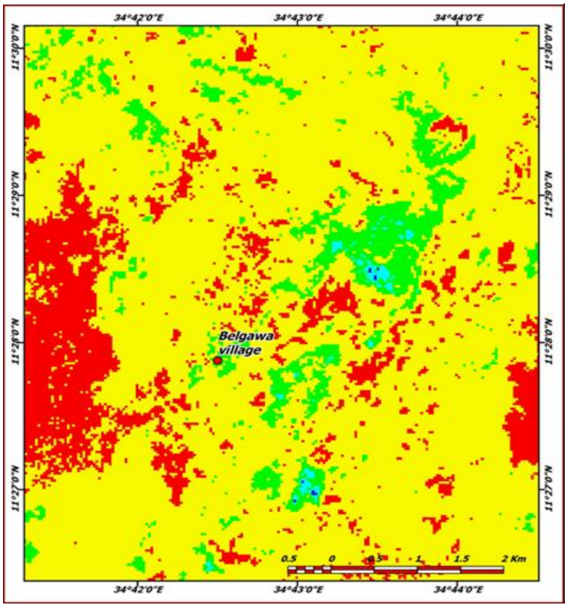


Fig (12)

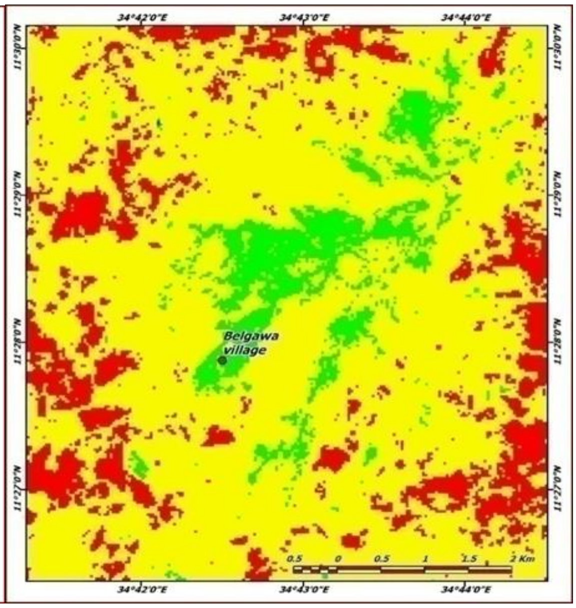


Fig (13)

Figure 12: NDVI color coded image, 9 November 1999, Belgawa

(NDVI color coded image obtained from Landsat 7 ETM+ data, path 171, row 52, acquisition date 9 November 1999. Red colors indicate health .and dense vegetation while green indicate light and poor vegetation cover)

Figure 13: NDVI color coded 21 November 2019, Belgawa

(NDVI color coded image obtained from Landsat 8 OLI data, path 171, row 52, acquisition date 21 November 2019. Red colors indicate health .and dense vegetation while green indicate light and poor vegetation cover)

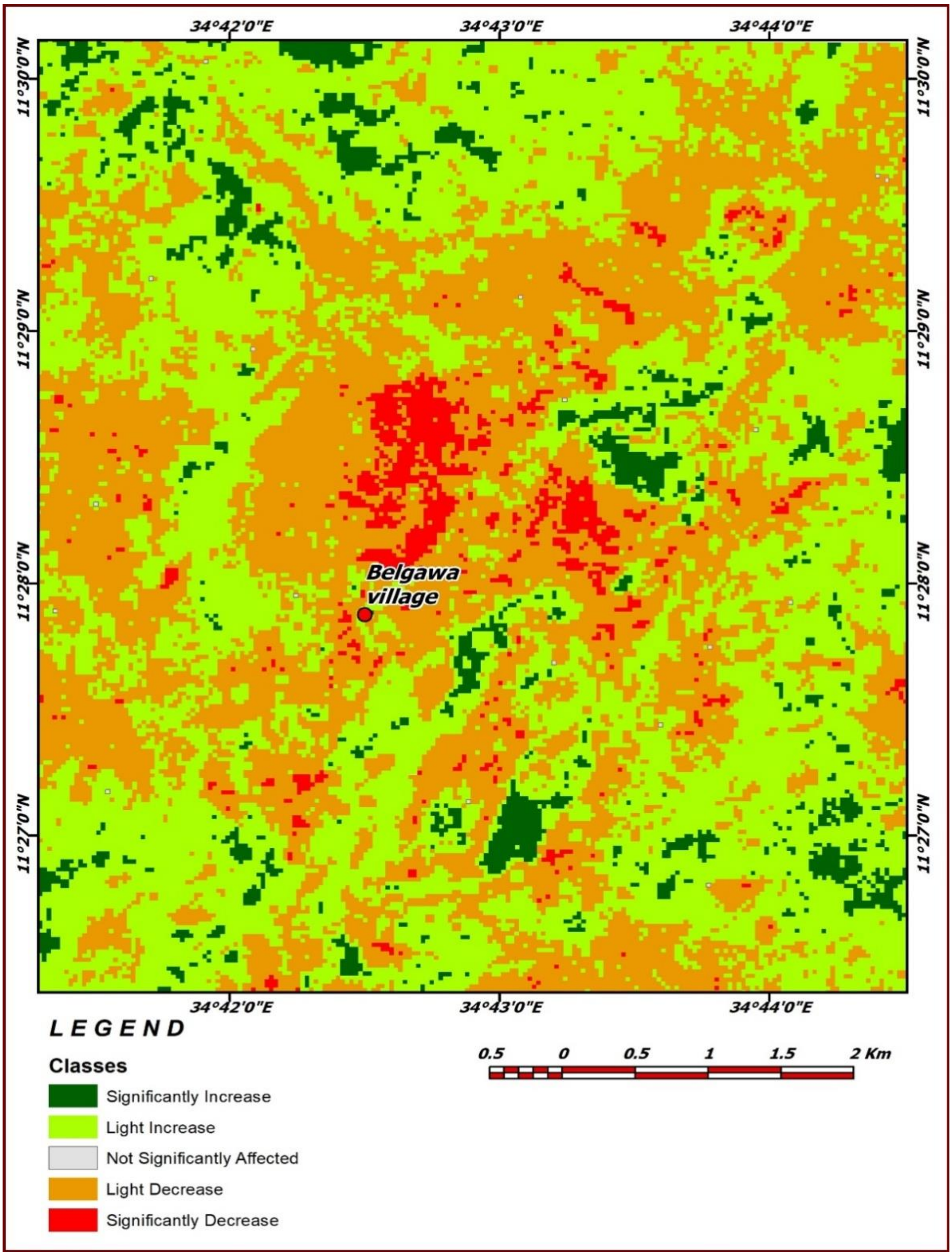


Figure 14: Change Detection image, 9 Nov. 1999 and 21 Nov. 2019, Belgawa

(Change Detection image obtained by temporal analysis of the NDVI images between 9 Nov. 1999 and 21 Nov. 2019.)

Change detection image obtained by temporal analysis of the NDVI images between 1999 and 2019 around J. Salmin (Um Saqata area, Gadarif state) where artisanal mining has been active for more than 15 years, shows that the area around the villages and the artisanal mining sites have decreased vegetation while inaccessible high lands remain unaffected (Fig.15, Table 7). Agriculture is dominant in the area and maybe the main driver for deforestation.

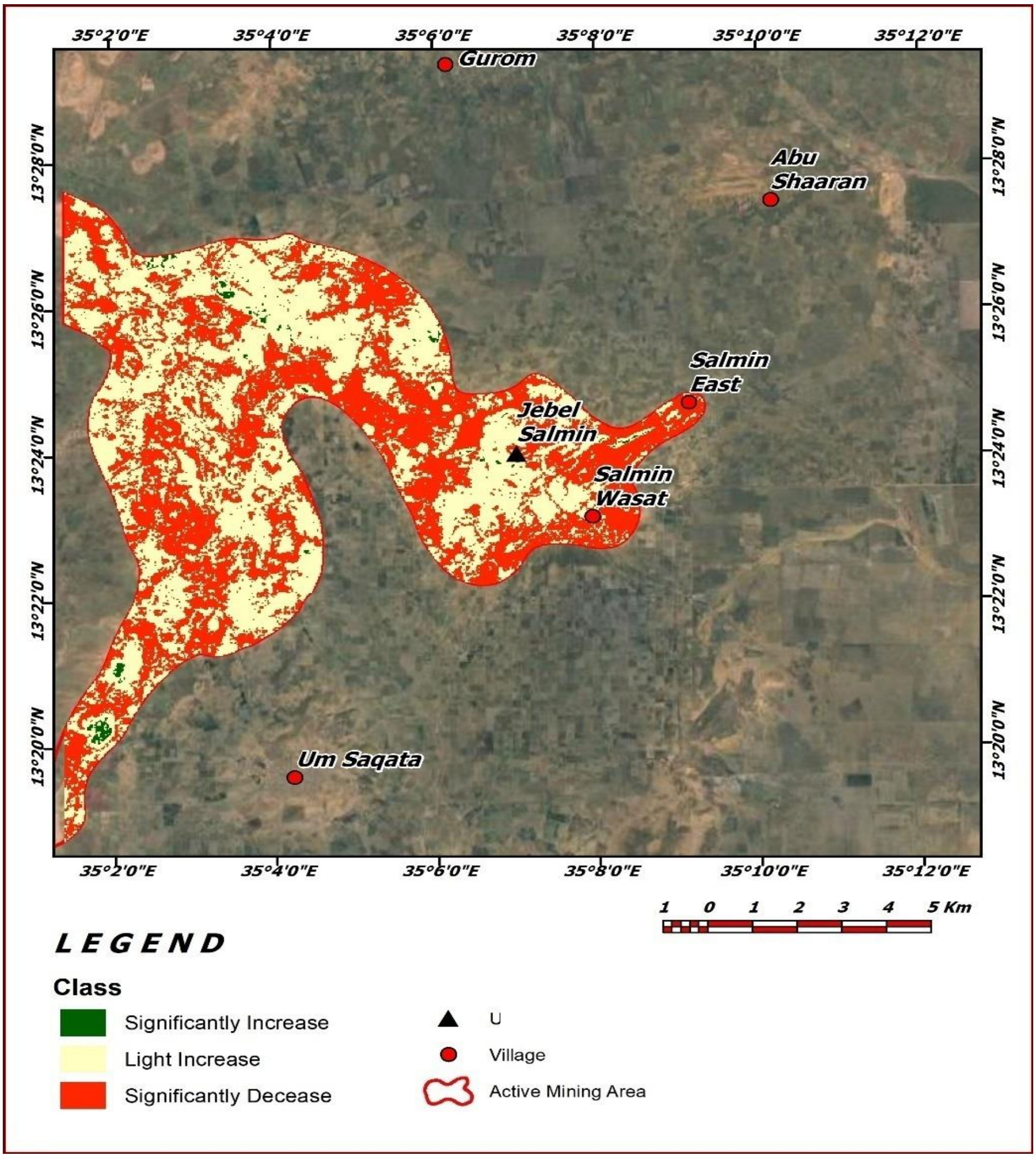


Figure 15: Change Detection image bet 9 Nov. 1999 and 21 Nov.2019 State, Um Sagata

(Change Detection image obtained by temporal analysis of the NDVI images between 9 Nov. 1999 and 21 Nov.2019 in Um Saqata area, Gedaref .State)

Table 7: Change Detection in Vegetation Cover, Nov.1999 – Nov.2019, J. Salmin

Class	Area Affected (feddans)	%
Light Increase	10,566	18.9
No Change	35,476	63.6
Decrease	9,605	17.2
High Increase	146	0.3

Based on the present expansion of mining in Sudan, a forest change map should be available to identify the hot spots for deforestation and degradation. These maps should include forest locations, human settlements, pastoralist routes, rivers, topography, and rainfall. The Strategic Environmental and Social Assessments (SESA) (Ecoact, 2018) identified five broad hot spot geographic areas which include forests: i) Riverine ecosystem of the Blue Nile and Sinnar state ii) Gum Arabic belt iii) Clay plain iv) Sand Plain v) Watershed forest of Jebel Marra.

The results obtained by the SESA study (Ecoact, 2018) on the impact of mining on forest ecosystems have shed more light on the importance of designating some of these sites as mining no-go-areas and others with high restrictions if mining is deemed justified in some of these hot spots. This study also necessitates the importance of revising and updating the current 2006 Forest Policy to incorporate mining as one of the drivers for deforestation and degradation of vegetation cover and include stipulations on related procedures on permits and reclamation of damages caused by mining.

4.3. Impact of Mining on Rangelands:

Rangelands in Sudan are defined as "Suitable land for the growth of range plants, used and recognized between pastoralists, according to the approved maps". According to the Aridity and Drought classification of UNESCO (1979) mentioned by Hassan & Tag Consultants (2018) in DoDD Study the Natural Rangelands: are grasslands, shrublands, woodlands that are, grazed by domestic livestock or wild animals.

Rangelands form an immense natural resource and the major source of feed for the national herd. The various types of grazing land vary from open grasslands to seasonal watercourses, flood plains, riverbanks, and associated islands, woodlands, hills, and mountain slopes. Reference to Sudan Land Cover Classes (FAO, 2012), available rangelands area calculated as 68.6 million hectares (35.6% of the total country area) represents herbaceous plants, shrubs trees categories (HCENR, 2015). Most of the country's forests are open or semi-open habitats, with 4% of Sudan's land area mandated as forest reserves that receive a special level of protection and management, those contribute significantly to browse (Badri, 2012).

Currently, there is no approved national rangelands policy; however, a number of national rangelands-related policies were adopted with the objective of reducing rangeland deterioration. Range and Pasture conservation stipulations are embedded in other natural resources policies and strategies. These policies and strategies have had limited success in achieving their objective due to the low priority assigned to range resources in the allocation of resources. This was aggravated by a lack of clear policies for environmentally sound land use; failure to consistently enforce pastoral land use rights and decentralized range resource management. Any impact on rangelands arising from mining activities is, therefore disregarded. With the current rate of deterioration of rangelands and the natural vegetation the need for a comprehensive policy and legislative framework that deals with land use in an integrated way is crucial.

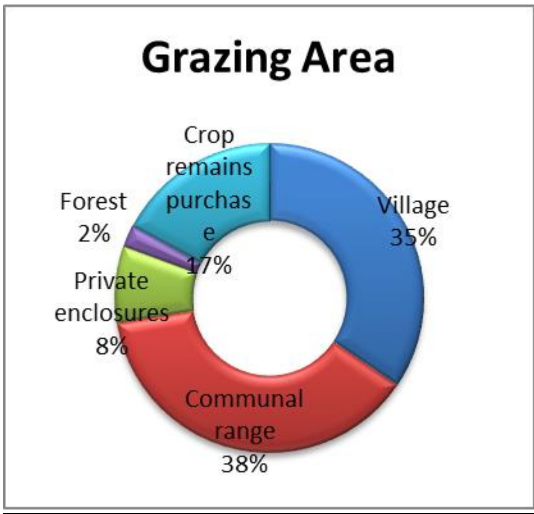
This study reveals that communities around mining sites feel that their rangeland disappeared, degraded or reduced in the area (Table 8). Miners and companies, however, do not see that negative impact. This is probably because they do not keep livestock. The community also thinks that the species combination was completely altered where palatable species were extinct and the nutritive value and the carrying capacity of the rangeland were much reduced due to mining activities. Species such As*sporobolus pungens* (Difra) and *Syperus spp* (Sedges)with high nutritive value have disappeared from the range while fewer value species such *Orobanche ramose* (Broomrape) and *Tribulus terrestris* (Puncture vine) are taking over. Mining pits created by artisanal miners create another danger for community rangelands. Companies are not exempted but mostly insensitive towards rangeland conservation as depicted in Table (8).

In Blue Nile State areas of rangelands are affected by mining activities. The effect is mainly due to surface disturbance. Rehabilitation efforts at the state level include gathering and distribution of seeds, the opening of corridors for nomads, and creation of range enclosures.

Table 8: Impact of Mining on Rangelands

Impact on Rangeland	Perspective of stakeholders			
	Community	**Artisanal Miners**	**Ore Processors**	**Companies**
Disappeared	20%	4%	2%	-
Degraded	41%	21%		25%
Area decline	16%	11%	12%	-
Species extinct	20%	4%	25%	-
Has no negative effect on rangeland	4%	60%	61%	75%
Total	**100%**	**100%**	**100%**	**100%**

Communities mostly graze their animals in the village and in the communal land surrounding the village and sometimes use the nearby agricultural remains. In areas where mining sites are close to villages, which is the case in most villages visited (70%) as depicted by (Fig. 16), the distance from mining sites is less than 3 Km. This situation renders animals and humans vulnerable to pollution caused by mining activities. This pollution in addition to deterioration of quality and are of rangeland is accompanied by water and air pollutions directly affecting the health of both animals and humans.



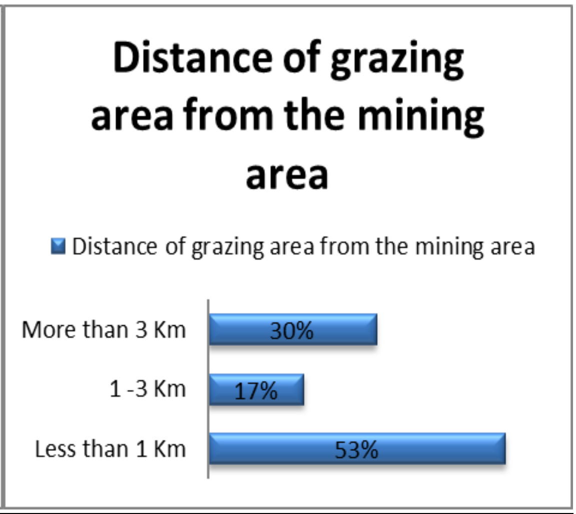


Figure 16: Distance of Grazing Area from Mining area

4.4. Impact of Mining on Wildlife:

Mining, if not well managed, is an inherently destructive industry, and the mining effects of even a single operation can have a severe impact on the environment and the wildlife that lives nearby. Although there are some regulations in place that are intended to minimize the damage, they are not enough to allow mining and wildlife to exist in harmony, especially in cases where the regulations are difficult to enforce. The mining industry has the potential to disrupt ecosystems and wipe out wildlife populations in several different ways, mainly habitat Loss. Mining can lead to the destruction of habitats in surrounding areas and the process normally begins with deforestation. Mining companies are quite willing to access mineral wealth at the expense of intact forests.

Sudan's rich terrestrial biodiversity is subject to a number of threats including natural and human factors. Wildlife biodiversity in Sudan is facing numerous threats aggravated by unclear wildlife policy, and limited awareness and poor enforcement. Threats include armed conflict, expansion of agriculture into forests, rangeland and wildlife areas, uncontrolled fires in natural rangelands and forests, overgrazing, poaching, and the adverse impacts of the petroleum industry, artisanal mining and the sugar industry on natural habitats. Additionally, the continuous changes in land use in and around wildlife natural habitats have resulted in fragmentation of wildlife habitats reducing chances of wildlife survival and genetic diversity. Power lines, dumping sites, and used polluted water in petroleum production and mining areas are killing large numbers of wildlife, including migratory birds (including soaring birds) by direct collision, electrocution and poisoning.

Sudan has made strides towards conserving some of its key ecosystems through its Protected Areas system. However, the conservation status of biodiversity, especially wildlife, including in protected areas is unsatisfactory. The Wildlife Conservation General Administration (WCGA) has limited manpower and skills and is, therefore, unable to provide an effective presence in even all protected areas. Wildlife habitats, populations and varieties are generally declining. A wildlife policy has been drafted to give guidance for WCGA activities across the county. Currently, the wildlife policy is not final and there is no wildlife strategy or protected areas strategy in place. (Sudan Protected Areas Project, UNDP/GEF PRODOC-2019).

With the recent outburst of gold mining, additional stress on wildlife communities is experienced, especially in no-reserved areas. All stakeholders interviewed in this study, agreed that wildlife either disappeared or was greatly reduced. Only 4% of the communities visited think that wildlife was not affected Table (9). Wildlife is highly linked to forests which provide habitat, shelter and food. Deforestation has several effects. Birds, animals, and creatures that depend on trees and plants for food or shelter lose their homes or starve to death. Any remaining survivors are forced to relocate and find a new dwelling. Some mining methods cause further destruction, such as the use of explosions which to say the least, drives wildlife away.

Added to this, many stakeholders think that poaching and extreme droughts are also impacting wildlife severely Table (10). Several species which are commonly seen in mining areas disappeared. Mammals such as gezal, fox, monkey, wildcat and wolf are no longer seen. Rabbit's population decreased significantly. Wild birds such as houbara bustard (*Chlamydotis undulate*) and wild chicken (*Numida mleagris*) also disappeared. Even reptiles such as snakes and lizards have driven away. Mining usually attracts a lot of people, increasing the pressure on natural resources, including wildlife. Artisanal miners and community members reported several cases of wildlife mammals and livestock falling into mining pits. There are reports of birds poisoning by cyanide used by the big companies (Photos, 3 &4).

Table 9: Impact of mining on wildlife

Negative effect on Wildlife	**Impact of mining on Wildlife**			
	Community	**Artisanal**	**Ore Processors**	**Companies**
Not affected	4%	-	-	-
Reduced	6%	66%	61%	50%
Disappeared	62%	34%	39%	50%
Some reduced & some disappeared	28%	-	-%	-
Total	**100%**	**100%**	**100%**	**100%**

Table 10: Reasons other than Mining affecting wildlife

Reasons other than mining affecting wildlife	**Impact of mining on Wildlife**			
	Community	**Artisanal**	**Ore Processors**	**Companies**
Poaching	56%	63%	61%	25%
Extreme drought	27%	24%	30%	75%
Diseases	5%	12%	5%	-
Others	12%	1%	4%	-
Total	100%	100%	100%	100%

Photo 3 Photo 4

`

Leaching of gold tailings by cyanide in big plots is a big hazard for birds.

4.5. Impact of Mining on Livestock

It is expected that the impact on forests and rangelands will impact livestock. In areas where people depend on natural grazing, the impact was more severe compared to areas where people grow fodder to feed their animals. Communities think that goats and sheep are affected the most (Fig. 17) while camels and cows are less affected, probably because they are able to tap range land far from mining sites. As stated earlier, most of the palatable and nutritive grass species disappeared were replaced by less nutritive species.

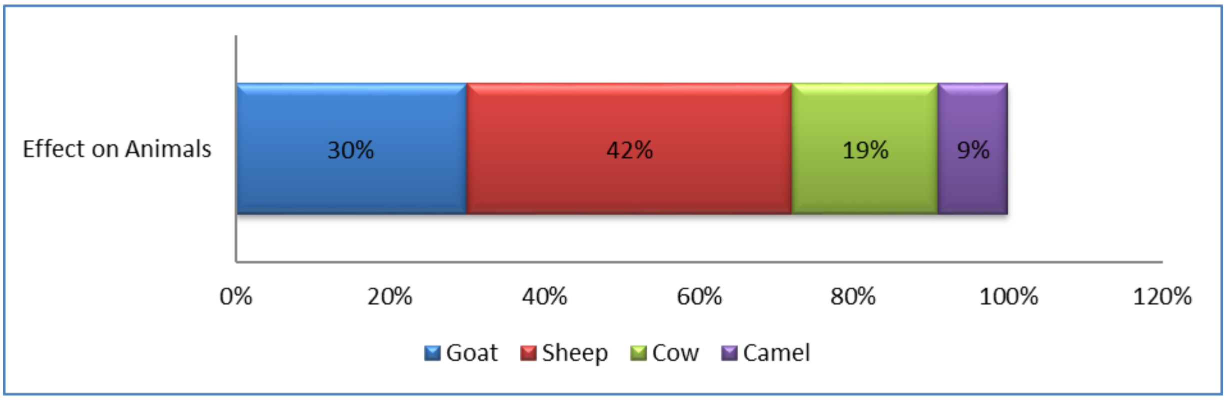


Figure 17: Impact of mining on type of livestock - community

Table 11: Impact of Mining on Livestock

Impact on Livestock	Perspective of Respondents			
	Community	**Artisanal**	**Ore Processors**	**Companies**
Death	32%	15%	4%	-
Diseases	15%	7%	14%	-
Productive reduction	53%	5%	9%	-
Disease & productivity reduction	-	1%		-
Has no negative effect on livestock	-	72%	73%	100%
Total	**100%**	**100%**	**100%**	**100%**

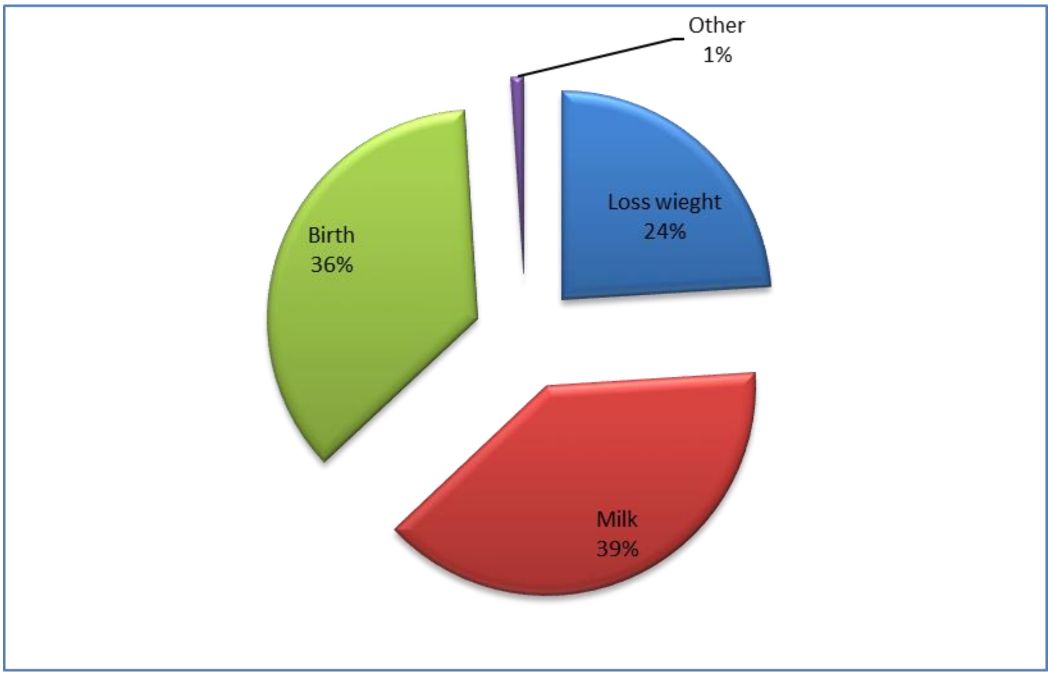


Figure 18: Impact of Mining on Livestock productivity -Community Perspective

The carrying capacity of rangelands is much reduced. All is reflected in the low productivity in meat and milk production (Fig.18). Communities also reported a sharp decline in birthrate and an increase in mortality rates caused probably by contamination of water resources and fallen in artisanal mining pits. Most the artisanal miners, however, think that mining is not affecting livestock (Table 11).

4.6. Impact of Mining on Agriculture

Agriculture by far has the largest impact on forests. The recent boom of mining in Sudan threatened agriculture itself. Mining is an inherently destructive industry, and the mining effects of even a single operation can have a severe impact on land use. Across all sites, communities think that there is a reduction in area available for agriculture as well as a reduction in productivity due to mining, (Table 12). About 9% 0f the community abandoned agriculture altogether. The major effect of mining on agriculture is the unavailability of labor. Labor migration to mining areas is very intense, which increased labor cost and consequently increased the cost of production. Mining disrupts the soil surface rendering it unsuitable for any other land use. These high-volume wastes, sometimes containing significant levels of toxic substances, are usually deposited on-site, in piles on the surface, or as backfill in open pits. Overturning the soil disrupts the soil profile and therefore, he topsoil most fertile is destroyed. The construction of access roads, either to provide heavy equipment and supplies to the mine site or to ship out processed materials and ores, can disturb agricultural lands as well.

Table 12: Impact of Mining on Agriculture.

Impact on Agriculture	Percentage			
	Community	Artisanal Miners	Ore Processors	Companies
Area Reduction	21%	15%	21%	50%
Productivity Reduction	20%	15%	19%	-
New Diseases	5%	6%	5%	-
Abandon of Agriculture	9%	18%	9%	25%
Labour Migration	31%	40%	32%	25%
Increase in Labour Cost/unavailability of labour	14%	6%	14%	-
Total	**100%**	**100%**	**100%**	**100%**

4.7. Impact of Mining on Water Resources

Mining impacts soil and water resources profoundly. These impacts defacing of landscape and the consequent change in the natural hydrology of the mining areas, pollution of desert's environment that occurs as a result of gold extraction through using toxic and hazardous substances such as mercury, and cyanide, acid drainage which threatens the neighboring rivers and ground waters (El Siddig and El Tohami, 2018). Therefore, pollution of ground and surface waters in nearby water body e.g. Gold-bearing during the rainy season where rainwater will wash these pollutants polluting the previously mentioned sources. Moreover, Artisanal gold mining has resulted in polluting the soils of the neighboring agricultural lands and rangelands.

Water supplies continue to dwindle because of resource depletion and pollution, whilst demand is rising fast because of population growth, industrialization, mechanization and urbanization. This situation is particularly acute in the more arid regions of the world. Mining by its nature consumes, diverts, and can seriously pollute water resources. South Africa has a long history of mining and has limited natural water resources, leading to a situation where it also has a number of significant rangelands challenges. With over 10, 000 km of hydraulically- interlinked coal mines and over 300 km of interlinked gold mines, mine-water challenges are not only at the local mine level but at regional level too (Vureen, 2009). A study by Naicker et al. (2003) revealed that the groundwater in the mining district of Johannesburg, South Africa, is heavily contaminated and acidified as a result of oxidation of pyrite contained in the mine tailings dumps and has elevated concentrations of heavy metals. Impact of mining activities on the landscape is very remarkable as mining activities require acquisition of large tracts of land.

The most fundamental component of sustainable development is to ensure that the streams, rivers, lakes and oceans are not contaminated due to human activities. Water is extensively used for various mining operations, viz., wet drilling, dust suppression, ore processing, and washing of heavy earthmoving machinery. Mine drainage, mine cooling, aqueous leaching and other mining processes have the potential to cause contamination of water bodies both surface and ground by discharging mine effluent and tailings seepage.

The main objective of Sudan National Water Policy (2007) is to; satisfy water needs for the development of the economy, poverty alleviation, environment protection and welfare of the citizens. On water quality, the water policy advocates for environmental conservation of the environment and ecological systems and protection of surface and groundwater from pollution. There are neither specific stipulations regarding the protection of water sources from pollution caused by mining activities nor any monitoring for water quality in mining sites.
Perhaps the most significant impact of a mining project is its effects on water quality. Acid mine drainage is a concern at many metal mines, because metals such as gold, silver, copper, lead and nickel, are often found in rock with sulfide minerals. When the sulfides in the rock are excavated and exposed to water and air during mining, they form sulfuric acid. This acidic water can dissolve other harmful metals in the surrounding rocks. For most mining projects, the potential of soil and sediments eroding into and degrading surface water quality is a serious problem.

More than 50% of the communities interviewed are of the opinion that drinking water was negatively impacted by mining to the extent of affecting both human and animal health. Artisanal miners and ore processors think that only humans are affected but not animals, (Table 13). Personal observations in Abydia area confirmed that the main pumping station for the town was located downstream very close to where mining heavy trucks, excavators etc. are washed at the main channel of the Gold-bearing and the drainage water flows directly into the river ,Photo (5&6). There are large numbers of dry mills in Abydia, which are considered the main source of particulate matters, where particulate matters are carried by the wind into the Gold-bearing due short distance between gold-bearing and Abydia market for grinding and processing of gold. The community attributes many of the chronic diseases to water pollution. Domestic animals wandering around processing plants and markets drink polluted water used in gold processing running in the open areas, Photo (7).

Table 13: Impact of mining on drinking water

Impact of Mining on Drinking Water	**Perspective of Respondents**			
	Community	**Artisanal Miners**	**Ore Processors**	**Companies**
Human	22%	28%	23%	-
Animal	1%	3%	2%	-
Both	53%	22%	19%	25%
Mining has no impact on drinking water	24%	47%	56%	75%
Total	**100%**	**100%**	**100%**	**100%**

Photo (5) **Photo (6)**

Photos (5&6): The wash drainage from heavy trucks is discharged directly into the Gold-bearing. Abydia village, Gold-bearing state

Photo (7)
Domestic animals around processing plants drink polluted water

In Belgawa area the community complains about drainage water from the mining site entering into their main drinking water source, the hafeer. All respondents agree that there is a reduction in water amount and that it is polluted, Fig. (19). Human diseases reported included diarrhea, malaria, dysentery, urinary tract infection etc. Diseases are also reported in livestock at rates higher than usual. New diseases such as Abu Riyalah (mouth and foot disease), Jaundice, water diarrhea, unknown diseases, and skin disease are not uncommon.

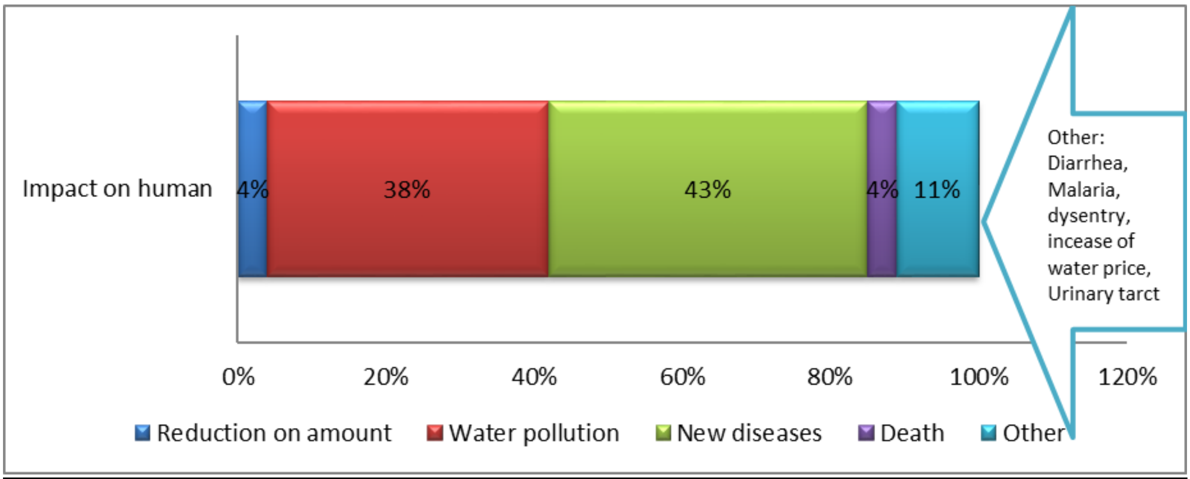


Figure 19: Impact of Mining on Drinking water for Human – Artisanal Miners

Soil and water samples were analyzed using Induced Coupled Plasma (ICP). Results were summarized in Table (14), Appendix (2). Most seriously is mercury levels in drinking water. The main source of drinking water for EL Subagh town is the hafeer (water pond). This natural depression accumulates water from different creeks. Drainage water from the ore processing area is also included. It should be noted that these samples were collected during the summer when the hafeer is almost dry. In Abydia the mining companies wash their heavy machinery at the special sites on the Nile only a few hundred meters upstream from Abydia drinking water station (Photo 5&6). The wash drainage is discharged directly into the Nile. In Belgawa mining water is pumped from inside the mine. This groundwater is heavily contaminated by organic and inorganic pollutants. Water samples from abandoned hafeer also reflected high levels of mercury. These values are away beyond the threshold limit set by WHO as 1ppb for Hg and 0.015 for Pb. Other heavy metals do not show variability between locations. Large amounts of mercury are released into the environment as a result of its usage in gold extraction. About 1.32 kg of mercury is lost for every 1 kg of gold produced which goes directly into water, soil, and streams as inorganic mercury and is later converted into organic forms. A study by Abdel Rahman (2018) indicated mercury levels in Nile water in Akasha village (North of Sudan) up to 2.8 ppb in a mining site near Wadi Halfa which is also beyond the threshold. Mining activities can lead to the generation of large quantities of heavy metal laden wastes which are released in an uncontrolled manner causing widespread contamination of the ecosystem (Fashola, et al., 2016)

Table 14: Heavy metal contents in water

Location	Element (ppm)			
	Cd (0.005)*	Ni (0.02)*	Pb (0.015)*	Hg (1 ppb)*
Tracks Washing drainage, Abydia	24.6	9.8	1.19	25.6
Drainage in Abydia	23.7	10.2	8.8	9.0
Belgawa mining water	25.0	9.8	5.6	11.5
Abydia drinking water Station	25.8	10.9	0.6	1.6
Subagh Hafeer	25.3	9.7	6.11	29.4
Hafeer Drinking water, Um Saqata	24.1	9.0	3.5	4.9
Hafeer drinking water, Belgawa	22.7	8.6	5.9	8.6

* WHO permissible limits for drinking water

4.8. Impact of Mining on Land and Soil:

Mining can contaminate soils over a large area. Agricultural activities near a mining project may be particularly affected. For most mining projects, the potential of soil and sediments eroding into a degrading surface is high. Major sources of erosion loading at mining sites can include open pit areas, heap and dump leaches, waste rock and overburden piles, tailings piles and dams, access roads, ore stockpiles, vehicle, equipment maintenance areas, and exploration areas. Soil erosion can be a serious problem at mining sites because of the large area disturbed by mining operations and the exposed large quantities of earthen material. Erosion may cause significant loading of sediments to the nearby villages and water resources especially, during severe dust storms. Dust created by hummer mills can travel more than one km, thus, can pollute plant, soil, and water surfaces, Photo (8). More than one-third of the respondents agree that the land at the mining sites is polluted and no longer suitable for other land uses. Mining pits reduced area of the land suitable for other uses Table (15), Photos (8, 9, and 10).

Most mining projects do not have any reclamation projects when the mining operations ended. Most large mining companies should apply Environmental Impact Assessment (EIA), related social studies, and strict mitigation controls within the confines of the mine. However, government control and enforcement of EIAs is often weak or totally absent as depicted by the study.

Table 15: Impact of Mining on Land

Impact	Percentage		
	Community	Artisanal Miners	Ore Processors
Pollution and unsuitability for Human activities	38%	43%	49%
Reduction of Land due to Mining Pits	22%	13%	18%
Hazards due to mining pits	40%	44%	33%
Total	**100%**	**100%**	**100%**

Photo (8): Hummer mill dust pollute land, plant, and water

Photos (9&10): Effect of artisanal mining on the landscape, (Um Saqata area), note the heavy disturbance of the soil surface. The pits constitute a hazard for livestock and wildlife.

Heavy metals in the soil include some significant metals of biological toxicity, such as Mercury (Hg), Cadmium (Cd), Lead (Pb), and Nickel (Ni). it is difficult to use dilution or self-purification techniques to eliminate heavy metal contamination and to get soils improved. Therefore, heavy metal contamination needs a relatively high cost of remediation and the remediation cycle is relatively long. All heavy metals examined in this study show abnormally high concentrations in the soil samples collected from artisanal mining sites in the four sites visited, Table (16). Most serious is the contamination of drinking water hafeers. This study showed that soils at the active mine sites contained significantly higher concentrations of heavy metals. The study indicates that artisanal gold mining activities caused severe soil degradation.

Table 16: Heavy metal contents in soil samples

Location	Element (ppm)			
	Cd (0.8)*	Ni (35)*	Pb (85)*	Hg**
Abydia ore processing site	24.0	6.21	30.64	17.6
Abydia abandoned ore processing site	22.4	6.81	6.14	15.4
Um Sagata artisanal mining site	25.2	7.95	7.27	19.3
Um Sagata tailings	22.5	8.04	1.44	18.0
Subagh hafeer	24.2	7.00	9.69	11.8
Subagh ore processing site	25.6	10.8	5.34	28.8
Belgawa abandoned hafeer	25.2	6.95	16.92	27.9

*** WHO permissible limits for soil. ** Hg is highly toxic, but volatile and readily lost from soil to air**

4.9. Impact of Artisanal Mining on Human Health

Artisanal Mining-related health hazards could be categorized as chemical, biological, biomechanical, physical, and psychosocial (WHO, 2016). Table (17) summarizes the common human health hazards associated with artisanal mining in Sudan.

- **Chemical Hazards**

Miners are susceptible to inhaling, absorbing and ingesting chemicals throughout the mining processes. The most common chemical exposures in mining operations are mercury used to amalgamate the gold, cyanide used to extract gold from tailings; and other chemicals contained in dust and gases.

Due to their small diameter and crystalline shape, silica dust particles generated during drilling, mineral extraction, ore crushing, and blasting, can be readily inhaled and deposited in the pulmonary tree (airways). Silica dust is toxic to lung tissue and to the immune system causing progressive scarring. Other minerals associated with gold include sulfides of iron, arsenic, lead, zinc, and copper. Toxic gases can also be generated from blasting such as nitrogen oxides, carbon monoxide and sulfur dioxide.

- **Biological hazards**

Biological hazards include water-borne and vector-borne diseases such as malaria, bilharzia, tuberculosis, cholera, etc.

- **Biomechanical and Physical Hazards**

Heavy load repetitive tasks and long working hours and unsafe equipment can lead to development of musculoskeletal disorders. Vibration, loud noise, heat and humidity and radiation, overexertion and physical trauma, burns, eye injuries, fractures are also common physical hazards**.**

- **Psychosocial Hazards**

This includes hazards such as drugs and alcohol abuse, fatigue, depression and stress.

Table 17: Common Hazards According to Mining Stage in Sudan:

N	***Stage of Artisanal Gold Mining***		***Possible Risk/Impact on Human Health***
1.	*Prospecting for gold nuggets using metal detectors*		*Effect of radiation of some metal detectors, bites of scorpions and snakes, sunstroke.*
2	*Excavation using hand tools or machinery, jack hammers, explosives in making mining pits and tunnels.*		*Physical injuries, dust inhalation (pulmonary tree problems), tuberculosis, sunstroke, hearing difficulties, inhalation of toxic gases (nervous system problems, poisoning), death.*
3	*Digging of deep bores or tunneling for gold ore and lifting of ore rocks and wastes.*		*Physical injuries, dust inhalation, suffocation due to lack of oxygen (toxic gases), vibration and noise (musculoskeletal disorders, overexertion and physical trauma, death due to rock falling and collapse of mines. These problems can be compounded by excessive heat and humidity which can also cause dizziness, faintness, shortness of breath or breathing difficulties and excessive thirst.*
5	*Primary crushing using crushing machines or hand tools at the pit site.*		*Physical injuries, prolonged dust inhalation can cause silicosis, chronic obstructive pulmonary diseases, tuberculosis and lung cancer, musculoskeletal disorders overexertion and physical traumatic injuries include burns, eye injuries, fractures etc..*
6.	*Transportation to grinding sites*		*Musculoskeletal disorders due to repetitive carrying of heavy loads.*
7	*Grinding*	*By Hummer Mill*	*Dust inhalation of silica and heavy metals cause skin diseases, progressive scarring, and damage to lung tissues and immune system. Dust contaminated with Lead can cause death, impaired neurocognitive development, premature birth.*
		By Water Wheel Mill	*Diseases due to mercury pollution such as kidney failure.*
8.	*Extraction by Mercury amalgamation and Mercury removal (burning off) processes*		*Elemental Mercury can cause: Excitability, irritability, excessive shyness, insomnia, tumors, kidney disease, acute gastrointestinal effects, pulmonary edema.* *Mercury (methyl-) bio-accumulated in the environment and food can cause: Visual disturbance, ataxia, hearing loss, mental deterioration, muscle tremor, movement disorders, and paralysis*

4.10. Impact of Mining on Women and children

Gold mining is usually dominated by men; however, women and children are also attracted by this business, especially in Blue Nile State. This study reveals that women are clearly involved in collection of gold-bearing rocks, and the ore washing process Photo (11&12). Women are also involved in providing many services in gold market areas such as food and tea making. Children are also involved in collecting leftover materials searching for gold. Salah and Elli (2020) confirmed that women and children are actively engaged in gold mining activities in Belgawa area in Blue Nile State.

Photo (11) **Photo (12)**

Women and Children practicing gold Mining in Belgawa, Blue Nile State (after Salah and Elli 2020)

4.11. Demographic effects

Artisanal miners are economically marginalized people using unregulated, improvised, and often harmful extraction methods. In some instances, populations in local towns or villages near major mines swell very rapidly. For instance, Geita township in Tanzania quadrupled in size within 3 years, from 30,000 residents in 1999 to 120,000 residents in 2002 (Lange, 2006). Such collateral development and immigration can have serious negative impacts on the environment. Local wildlife and forests are overexploited while local mining enterprises are often polluting, releasing toxic chemicals into rivers (Durand, 2012), including mercury in the case of gold extraction. Combined with huge increases in sediment loads, mercury severely alters the species composition of aquatic communities and bio-accumulates in fish (Gammons et al. 2006) and ultimately humans.

In Sudan, the demographic changes due to mining outburst are clearly noted in all visited sites. In recent years, artisanal miners move in large numbers seeking for gold anywhere new discoveries are heard of. Suddenly new big temporary settlements are created with no accompanying services. Therefore, miners live in very harsh conditions, no good drinking water and no good food or shelter. At the same time mining is depriving agriculture sector from well needed labour force. Artisanal miners come with their own norms and traditions, therefore affecting the resident communities' culture that may be not acceptable by locals.

4.12. Reclamation of Gold Mining Damaged Sites

Gold mining impact can be rated qualitatively as low, medium and high depending on the severity of the impact. This damage is rated similarly as for forests, based on:

i. Magnitude which refers to the intensity of the damage;

ii. Aerial extent which refers to the area of coverage of the damage;

iii. Duration which is the time needed to restore the area to its initial state prior to the mining impact and;

iv. Importance and proximity to no-go-areas such as water resources, settlements, archeological sites and forests reserved for protection purposes.

Accordingly, all mining sites should be assessed and classified, and the reclamation process starts with the sites of high rating.

Reclamation can be defined as a replacement of soil materials to its approximate original contour and re-vegetation of mine areas adjacent to mines that have been affected by mining activities. It can also be defined as the process of repairing any negative effects caused by mining activities on the environment. The land reclamation should serve the following:

1- Prevent negative impacts on soil, water and air resources.

2. Restore the quality of soil to their pre-mining level.

3. Maintain and improve landscape and functional quality.

4. Conservation and restoration of ecosystem services.

5. Conservation of forest, range and wildlife habitats.

It worth mentioning that, reclamation can be expensive endeavour. Therefore, it is required that sufficient funds are available for reclamation. Collaborative efforts between mining companies, government and conservation organizations are necessary to promote successful mine reclamation.

For open cast mines replacement of overburden that was removed or repositioned, re-landscaping or re-contouring along with drainage control measures to create a suitable rooting medium for good tree growth that is not less than 4 meters. Underground mines should be filled with excavation materials, care should be taken not to contaminate groundwater.

Water harvesting techniques can be adopted to increase tree survival, in this respect it is suggested to plant drought tolerant trees such as Acacias and Sidir (*Ziziphus spina Christi*) in central and southern Sudan mining sites. IFAD rehabilitation project in Butana region used mining pits as water catchments for planting trees which can be expanded to other similar mining areas as a successful model (Photo 1&2). Mining sites in dry areas, where rainfall is very meager to support plants, then restoration of the land surface should at least be made.

It is noticed that tailings produced by the artisanal mining water and air mills is a major source of contamination. These tailing are kept in highly populated markets in huge heaps and subject to wind, rains and underground seepage (Photo 13&14). These tailings when transported to companies are then treated differently and dealt with in a more protective manner. In all companies' sites visited, tailings are stored in pits/heaps underlined by thick plastic sheets to prevent leaching of chemicals into the soil and covered to reduce wind blowing. The tailings are kept for future possible re-extraction. It is recommended that this good practice be adopted by artisanal miners and enforced by authorities.

Photo (13) **Photo (14)**

Unprotected heaps in gold markets caused by artisanal miners.

4.13. REDD+ and Artisanal Gold Mining

There is potential mutual conflict between interventions aimed at formalizing artisanal and small-scale mining on the one hand and policies implemented in response to the Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiative on the other hand. The expected outcomes of the REDD+ programs are to support national goals of the conservation of the country's renewable natural resources and facilitating sustainable land use management, eventually providing benefits to the community that depend on forest and other natural resources as mentioned in DoDD study (Hasan &Tag, 2018).

Artisanal mining while providing opportunities for benefits and livelihood support for large number of people in Sudan, it can be a source of negative effect on natural resources. Artisanal mining practices have so far produced documented chemical, physical and biological damage to natural resources in areas where there are intensive mining operations.

Managing environmental impacts of mining activities by concession companies is governed by policies and laws, while artisanal mining environmental impact on natural resources remains very challenging. The current forests and other natural resources polices (Range and pasture, Water, wildlife and soils), has no clear stipulations regarding mining, specifically artisanal mining. This might be due the fact that mining outburst is very recent in the country while these policies are relatively old. This entails that the REDD+ program should promote review of all policies related to natural resources management to accommodate mining. At the implementation level the REDD+ can help in identification and reclamation of the damaged areas and promote adoption of best practices in Sudan and globally.

The REDD+ strategies on deforestation, land degradation and social changes due to artisanal mining operations must incorporate tailored activities to address the following interlinked types of damage:

i) Physical damage on the earth surface caused by mining operations. This damage is caused by miners while searching for gold creating different sizes of pits. The depth of these pits can reach tens of meters and the surface cover of one pit could go up to hundred square meters. These mining pits are one of the main hazards for human and animals in mining sites.

ii) Chemical pollution resulting from the processing operations for gold extraction from the ore. These operations involve use of harmful chemicals such as Mercury and release of heavy metals such as Lead (Pb), and Cadmium (Cd) in designated processing areas. Unlike the uncontrolled physical damage expansion, the chemical environmental damage is confined to limited gathering sites established by the Government. However, it could also be carried away by wind and water to contaminate other far away areas.

iii) Biological damage resulting from tree cutting for energy, building materials and mines supportive, extinction and change of species composition in range and forest land and poaching of wildlife.

iv) Social and cultural change resulting from the influx of artisanal miners coming from communities of different cultural backgrounds which might not be acceptable to local communities and hence lead to conflicts.

Integrating extractives industries such as gold mining in REDD+ strategies could make an effective contribution to emission reductions, while at the same time contributing to forest carbon-stock monitoring and reporting processes.

REDD+ program in promoting rehabilitation of artisanal mining sites should embark on establishing strong partnerships with Ministry of Mining, local authorities including locality, FNC, Range and Pasture, Wildlife, local communities, NGOs, CBOs, donors, UN organizations and the private sector. Such program should consider adoption of local and global best practices for using mining pits as water catchment structures for water storage and/or planting trees. On the other hand, preventive measures can help in protecting water sources from waste drainage.

Chapter 5: Findings and Recommended Actions

Finding	Recommended Actions	Responsible Parties
Policies		
Natural resources *1- Sudan is lacking a comprehensive policy and legislative framework that deals with land use in an integrated manner. Rather, there are a number of individual sectoral policies e.g. agriculture, forestry, wildlife, mining, oil and other resources. However, implementation of these policies is challenging because there is a lack of coordination between the multiple authorities involved, limited resources and widespread corruption.*	*1. Review of all-natural resource policies to accommodate the impact resulting from the recent outburst of mining. This also includes identification of* ***no-go-zones*** *for mining* *1.2 Establishment and enforcement of new policy/law stipulations to govern the environmental impact of artisanal mining.*	*1. Authorities of Forestry, Wildlife, Range and Pasture, Agriculture, water, Archeology, and Mining.* *1.2.1 HCENR, Ministry of Mining, FNC, Range and Pasture, Agriculture, Wildlife, Archeology, Water.*
Legal Mining *2. Policies, legislation, licensing on mining and stipulations on environmental conservation and protection exist, however, need to be strengthened and implementation and monitoring need to be enforced.*	*2.1 Review of the licensing procedure at the federal and state level to ensure enough scrutiny and clearance of relevant natural resources authorities.* *2.2 Establishment of strong and appropriate mechanizm for the review and approval of EIA and Environmental plan for mining concessions.* *2.3 SMRC undertakes to monitor the environmental impact of mining activities independently from mining companies.* *2.4 Natural Resources Institutions and local authorities should engage in joint monitoring of mining activities to detect early signs of deforestation and land degradation, water pollution and take necessary actions.*	*2.1.1. Ministry of Mining, State Government, Forestry, Wildlife, Water, Range and Pasture and Agriculture.* *2.2.1 The Higher Council for Environment and Natural Resources.* *2.3.1 SMRC in collaboration with NR relevant authorities and government localities.* *2.4.1 SMRC in collaboration with NR relevant authorities and government localities.*
Artisanal Mining *3. The Sudan mining code (2017) focuses on legal mining and concession with very general stipulations on artisanal mining. No specific or detailed framework, laws, or legislation*	*3.1 Establishment of a comprehensive legal framework including policies, laws, bylaws, legislations to govern, regulates, and control artisanal mining in Sudan.* *3.2. Introduction of environment-friendly technologies and*	*3.1.1 Ministry of Mining (Leading), Natural Resource authorities, research institutions, Civil society and private sector.* *3.2.1 GRAS, Research institutions, REDD+,*

governing or organizing this sector. *All recent consultations stress the need to establish such a legal framework.*	*new approaches to ensure safety and environmental protection and health measures to reduce the adverse effects of mining (Adoption of best practices from other countries).*	*International organizations.*
4. The artisanal mining sector contributes over 85% of gold production, moreover, it has contributed substantially to employment and peoples' livelihoods. However, benefits are not evenly distributed it is also a source of damage to the environment and social conflicts.	*4.1. Formalization of the artisanal mining sector will lead to greater transparency and control of conflicts. Formalization may include:* *- Creation of conducive and appropriate legal and policy frameworks.* *- Provision of legal access to minerals for small-scale mining sector including designated specific areas.* *- Creation of dynamic associations for artisanal miners.* *- Mainstreaming of artisanal mining into the country's economic program.* *- Provision of artisanal miners with geological information for more efficient mining.* *- Provision access to capital and equipment and technical assistance.* *- Provision access to formal minerals markets.* *- Establish clear institutional mandates and decentralize roles with the local and regional government so that services can be brought directly to miners.* *- Creation of space for participation and engagement of different stakeholders in policy-making, paying special attention to vulnerable and marginalized groups, such as women and indigenous population.*	*4.1.1 Ministry of Energy Mining and state authorities.*
Institutional Concerns		
Legal Mining Sector *5. Mandates and roles of the four main institutions under the*	5.1. *Restructuring of the Ministry of Mining with objective of establishing efficient and effective*	*5.1.1 Ministry of Energy and Mining*

Ministry of Energy Mining, namely; GRAS, SMRC, Sudamin & Ariab Co., are not well coordinated with regard to licensing, monitoring, and services.	*institutions with clear mandates. Clear and proper licensing procedures, monitoring of implementation and reclamation of environmentally damaged sites.*	
6. Corporate Social Responsibility (CSR) of the large investment gold companies has produced minimal or no improvement in people's livelihood in terms of infrastructures, jobs and services. Despite the fact that companies meet their obligations on CSR but it is not translated into a developmental change in areas surrounding mining sites. This has created documented disputes and hostility between communities and concession companies.	*6.1. Government to introduce a new law on CSR to allow concession big and small companies to directly design and implement CSR projects in close collaboration and consultation with the communities and local authorities.* *6.2 Establishment of a monitoring mechanizm to oversee implementation of the CSR projects.*	*6.1.1. SMRC, Local Government (State and Locality), civil society and communities.* *6.2.1 Jointly by the locality, community and the gold mining compan*ies.
Artisanal Miners: *7. Artisanal miners are huge in numbers, coming from poor and low educational backgrounds, low in capital and therefore, difficult to deal with. These characteristics make their behavior careless towards their own safety and the environment and natural resources around them.*	*7.1 Improve management of artisanal mining by organizing them in small groups/associations to facilitate enforcement of environmental laws and raising awareness on safety, health and environmental protection (acknowledged best practices).* *7.2. Establishment of local bylaws to protect natural resources, animals and human in the vicinity of mining sites and enforce it through miners associations.*	*7.1.1&7.2.1 Local authorities guided by State government and Natural Resource authorities, Ministry of Energy and Mining and HCENR.*
8. Low capacities on the part of institutions entrusted with natural resource management to deal with conventions and treaties related to mining specifically gold as well as its adverse impact on the environment.	*8.1 Extensive and tailored awareness and capacity-building programs for all related institutions on gold mining activities.* *82. Raising awareness of institutions, communities and civil society on related conventions and treaties.*	*8.1.1 &8.2.1. REDD+ Program, Ministry of Energy Mining, Civil society, research institutions, donors and UN organizations.*
Environmental Concerns and Reclamation of Mining sites		
9. Mining activities have resulted in physical, chemical, biological and social	*9.1 Reclamation of physical damage by*	*9.1, Sudamin Co., Mining companies,*

damages that need to be addressed. *Examples of these are:* *i. Physical disturbance of land surface rendering it prone to wind and water erosion, removal of fertile topsoil, creation of pits hazardous to human and animal, and reduce land suitability to other uses.* *ii. Chemical pollution by Mercury, cyanide and other heavy metals especially at the processing sites inside market complexes. Resulting contamination can affect lands and water bodies, and agricultural sites, etc.* *iii. Biological damage which includes: tree removal, disturbance of spp. mix, disturbance of soil fauna and flora, destruction of the soil seed bank, destruction of habitat for wildlife.* *iv. Social damage: disturbance of community culture and norms, creation of significant demographic changes due to the high influx of people in new areas creating more pressure on weak services, increase of disputes, conflicts and crimes.*	*backfilling of pits, using pits as water catchment and tree planting, restore land contour and soil profile.* *9.2 Enforcement of Minamata convention regarding use of Mercury, avoiding processing sites from water natural drainage and community settlements, tailings at market sites should be covered and underlined with plastic sheets to prevent wind and water erosion and seepage.* *9.3 Tree planting, re-introduction of extinct spp., enrichment of soil seed bank through seed broadcasting, restoration of ecosystem services. Creation of protected areas (No-go-zone)* *9.4 Increasing awareness of communities. Solving land tenure issues, strengthening security, quick response from local authorities through the provision of services (drinking water, health services, food, fuel etc.)*	*Natural resource institutions, NGOs and community.* *9.2 SMRC, HCENR, Mining companies, Local Government,* *9.3 FNC, Rangeland Department, NGOs, Wildlife Authority, International Organizations* *9.4 National and local media, Ministry of Interior (Mining police force), Ministry of Culture and Heritage.*
Natural Resources		
Forestry *10. Miners use forest resources for energy, wood for huts construction, unemployed artisanal miners and traders get engaged in charcoal making and firewood collection. Strong woods poles are used as underground mines support.These activities cause deforestation and land degradation around mining sites.* *11. Mining activities inside and close to forests cause disturbance of tree species mix. It is evident that many spp such as Talih (Acacia seyal) and Sahab (Anogeissus leiocarpus), Habeel, (Combretum hartmanianum), Ebony (Diospyros spp) and Hashab (Acacia senegal) have disappeared or rarely seen*	*10.1. Dedicated and close monitoring of forests/vegetation cover in the vicinity of mining sites.* 11.1. *Establishment of forest change map to identify the hot spots for deforestation and degradation. These maps should include forest locations, human settlements, pastoralist routes,*	*10.1.1. FNC in collaboration with communities, localities and SMRC.* 11.1.1. FNC

around the mining sites. In Belgawa Ebony was targeted by miners for underground mining support. *12. The indirect impact of artisanal mining on forests includes; infrastructure development such as roads which could lead to exploitation of forests for commercial firewood and charcoal;* *13. Gold mining is a driver of land degradation and deforestation and hence affecting carbon stocks, and CO2 emissions*	*rivers' topography, and rainfall. This map will help to detect vegetation change at early stages and take necessary actions for rehabilitation such as the re-introduction of affected spp.* *12.1. Promote use of alternative energies such as LPG in mining sites* *13.1. Implementation of reclamation projects of forest/vegetation cover sites damaged by mining activities by restocking of damaged forests.* *13.2 Integrating extractives industries such as gold mining could make an effective contribution to emission reductions, while at the same time contributing to forest carbon-stock monitoring and reporting processes.*	 12.1.1 FNC, REDD+ Program 13.1.1 FNC, HCENR, NGOs and International organizations. *13.2.1 REDD+*
Rangeland *14. Mining pits made by artisanal miners and gold companies create danger for community rangelands both are not insensitive towards rangeland conservation. Disturbance of soil seed bank, species such as Difra (Sporobolus pungens) and Sedges (Syperus spp), with high nutritive value have disappeared while fewer value species such Broomrape (Orobanche ramosa) and Puncture vine (Tribulus terrestris) are taking over.*	*14.1 Rehabilitation efforts include gathering and distribution of seeds, opening of corridors for nomads and creation of range enclosures.*	*14.1.1 Range land authorities, Private sector*
Wildlife *15. Deforestation and forest degradation due to mining cause loss of habitat for wildlife. Birds, animals, and creatures that depend on trees and plants for food or shelter lose their homes or starve to death or migrate. Disruption of wildlife routes.* *Loss of several species which are commonly seen in mining areas. Mammals such as gezal, fox, monkey, wildcat and wolf are no longer seen. Rabbit's population decreased significantly.* *Several cases of wildlife mammals and livestock falling into mining pits are*	*15.1 Establishment of protected areas, and No-Go-Zones.* *15.2 Empowering Wildlife authorities for close monitoring in the mining sites.* *15.3 Re-introduction of extinct species into protected areas.* *15.4 Increasing awareness of the importance of wildlife in the ecosystem for all miners.*	15.1.1 Wildlife Authorities 15.1.2 Wildlife Authorities 15.1.3 Wildlife Authorities 15.1.4 Wildlife Authorities

reported. Poisoning of mammals and birds by cyanide used by big companies. Noise due to explosions and machinery drive wildlife away.	*15.5 Physical reclamation of abandoned mining pits.* *15.6 Covering of cyanide basins and other polluted waters used for gold extraction by gold companies.*	15.1.5 Sudamin Co. 15.1.6 Gold Mining Companies, SMRC
Drinking Water *16. Perhaps the most significant impact of mining is its effects on water quality. Acid mine drainage is a concern at many metal mines. This acidic water can dissolve harmful metals in the surrounding rocks. For most mining sites, soil and sediments eroding into water sources is a serious problem affecting both human and animal health.* *In Abydia, the main pumping station of the town is located downstream very close to where mining heavy trucks, excavators etc. are washed at the main channel of Gold-bearing and the drainage water flows directly into the river.* *There are large numbers of dry mills in Abydia market, which are considered the main source of particulate matter that can be carried by the wind into the gold-bearing.* *Water samples collected from abandoned hafeers in Belgawa, Salmin and Al Subagh villages reflect high levels of mercury way beyond the threshold limit set by WHO.*	*16.1 Gold processing sites should be selected such that their drainage should not contaminate water sources. Acid drainage should be collected into special protected places and be treated before release into the environment.* *16.2 Strict prohibition of washing of machinery and any related mining equipment near water sources and natural water drainage.* *16.3 Encourage research to develop physical, chemical and bio-remediation reclamation techniques for the affected sites.*	*16.1.1 SMRC, Local government, mining companies, Water & Health authorities, SMRC.* *16.2.1 Local authorities.* *16.3.1 Sudamin Co., National Research Centers NRC*
Agriculture *17. Mining disrupts the soil surface rendering it unsuitable for any other land use. Overturning the soil disrupts the soil profile and the topsoil most fertile is destroyed causing yield reduction.* *Soil pollution by mercury and other heavy metals changes soil fauna and flora. The uptake of heavy metals constitutes a great health hazard.* *Unavailability of labor. Labor migration to mining areas is very intense, which increase labour cost and consequently increase the cost of production and area planted.*	*17.1 Solving land tenure disputes between agriculture and mining.* *17.2 Reclaiming the affected sites* *17.3 Use of agricultural machinery to reduce dependence on labor.* *17.4 Use of tolerant and high-yielding crop varieties.*	17.1.1 Local government, Ministry of Agriculture, Ministry of Energy and Mining. 17.2.1 Sudamin. Co., Ministry of Agriculture. 17.3.1 Ministry of Agriculture. 17.4.1 Ministry of Agriculture, National Research Center.
Land and soil *18. Physical damage includes; mining pits, disruption of the soil profile, wind and water erosion, compaction caused by heavy machinery, waste rocks and overburden, tailings dumping.*	*18.1 Reclamation of mining pits; restoration of soil fertility, stabilization of loose soil surfaces.* *18.2 Dumping of mining wastes in confined*	*18.1.1 Sudamin Co., Mining companies, Local government.* *18.2.1 SMRC, Mining Companies*

Chemical pollution is due to the release of heavy metals and toxic substances. Biological disturbance of soil fauna and flora.	*selected sites.* *18.3 Use of chemical and bio-remediation techniques.*	*18.3.1 Sudamin Co. , SMRC, provision of funding to Research institutions*
Health and safety: *19**.** Health hazards can be divided into: physical, chemical, biological and Psychosocial and can be associated with different mining stages**.*** ***Physical:** Heavy load repetitive tasks and long working hours and unsafe equipment can lead to the development of musculoskeletal disorders. It also includes vibration, loud noise, heat, humidity, radiation, overexertion and physical trauma, burns, eye injuries, fractures**.*** ***Chemical:** Inhaling, absorbing, and ingesting chemicals throughout the mining processes. The most common chemical exposures in mining operations are mercury used to amalgamate the gold, cyanide used to extract gold from tailings; and other chemicals contained in dust and gases. Silica dust is toxic to lung tissue and to the immune system. Toxic gases such as nitrogen oxides, carbon monoxide and sulfur dioxide can also be generated from blasting.* ***Biological hazards:** Include water-borne and vector-borne diseases such as malaria, bilharzias, tuberculosis, cholera, etc.* ***Psychosocial Hazards:** Include hazards such as drugs and alcohol abuse.*	*19.1 Adoption of safety measures for all those involved in mining.* *19.2 Increase the awareness of mining hazards.* *19.3 Establishment and strengthening of health centers in mining sites and nearby settlements.* *19.4 Periodic health surveys and studies to identify health problems within mining communities.* *19.5 Availing of drinking water and adopting general sanitation measures.* *19.6 Social survey, better working relations between investors and workers.*	*19. (1, 2, 3, 4, 5) Ministry of Health, Research institutions, NGOs. Ministry of Social Welfare.*

Epilog

Mining is destructive activity to the environment. The most significant impact of mining activity is the migration of people into a mine area, particularly in remote parts. This influx of newcomers can have a profound impact on the original inhabitants, and disputes may arise over land and the way benefits are shared. Sudden increases in population lead to pressures on land, water, and other resources. Improved infrastructure can also bring an influx of settlers. When mining activities are not adequately managed, the result is degraded soils, contaminated water, lost biodiversity, and forest resources, which are critical to the subsistence of local people. When contamination is not controlled, it affects other economic activities, such as agriculture, pasture, and wildlife. Contamination also has a profound effect on the health of humans and animals. The situation is made worse when mining activities affect women, children and, other marginalized groups. Proponents of mining projects must ensure that the basic rights of affected individuals and communities are upheld and not infringed upon. These include rights to control and use land, the right to clean water, and improved livelihood in terms of infrastructures, jobs, and services. Proper mining policies should be put in place to ensure maximum benefits while maintaining the environment. Gold mining rendered a lot of land unproductive through physical and chemical degradation and hence increases the vulnerability of the community to climate change. Environmental impact assessment should be conducted in all mining projects as a planning and decision-making tool with the objective of minimizing or avoiding adverse environmental effects before they occur and incorporate environmental factors into decision making including risk management.

References

Abdel Rahman, M. S (2018): Saar El Zahab (*in Arabic*): Environmental and social cost of mining. Gezirat El Ward Library (pub.) Egypt, 288 p.

Alvarez, B. N.L, Aide, T.M. (2015): Global demand for gold is another threat to tropical forests. Env. Res Letters 10(1). DOI: 10.1088/1748-9326/10/1/014006.

Atta El Moula, M.E. (1985): On the problem of resource management in the Sudan. Institute of Environmental Studies, University of Khartoum. Environmental Monograph No. 4.

Ash, P.(2013): Demand for resources drives African rail boom. Rail market intelligence from the team behind International Railway Journal. http//:www.railjournal.com

Badri, S. (2012): Sudan environmental threats and opportunities assessment with special focus on biological diversity and tropical forests. A report conducted by the United States Agency for International Development (USAID), pp. 1-25.

Blue Nile Investment Map (2004): Blue Nile State Government.

Dobson, A. P., Borner, M., Sinclair, A.R.E., Hudson, P. (2010): Road will ruin Serengeti. Nature, 467(7313): 272-3.DOI: 10, 1038/467272a.

Docena, H. (2010): Philippines: Deforestation through mining subsidized by CDM project. WRM's bulletin No. 161, Dec. 2010.

Durand, G.F.(2012): The impact of gold mining on the Witwatersrand on the rivers and karst system of Gauteng and North West Province, South Africa**.** Journal of African Earth Sciences 68(15):24–43

Durkin, T.V., Herrmann J.G. : Focusing on the Problem of Mining Wastes (2016) : An Introduction to Acid Mine Drainage, EPA Seminar Publication No. EPA/625/R-95/007. [(accessed on 11 March 2016)]. Available online: http://technology.infomine. com/enviromine/publicat/amdintro. html.

Ecoact UK (2018): Strategic Environmental and Social Assessment (SESA), final report. Sudan REDD+ Readiness Program.

El Siddig and El Tohami (2019): Seasonal Flood and its Environmental Health and Socio-economic Impacts on Livelihood. Review of A five –year period. Am. J. Biomed. Sci. & Res. 2019 – 5 (4)

FAO, (2012): Sustainable Pastoralism and rangelands in Africa. J. Nature and fauna. Vol.31, issue. No.2,

Fashola, M.O., Ngole,V.M. and Babalola, O.O. (2016): Heavy metal pollution from gold mines: environmental effects and bacterial strategies for resistance. Intern Jour. of envi. res. and pub. health, 13, 1047.

Gammons, C.H.,Twidwell, L.G., Young, C.A. et. al., (2006): Summary of Deepwater sediment/Pore Water characterization for the Metal-laden Berkely pit Lake in Butte, Montana. Mine water environ 25. 86-92.

GEO Services International, (2015): Impact of Traditional Mining of Gold on the Social and Economic Life in Sudan and on the Environment.

Hassan & Tag Consultants (2018): In-depth analysis of Drivers of Deforestation & Forest/Range Degradation DoDD, Sudan's National UN-REDD+ Program.

Higher Council for Environment and Natural Resources (HCENR): National Biodiversity Strategy and Action Plan 2015 -2020.

Khalil, B., Salih, S. A., El Tom, G. A. (2005): Mining is a significant cause of desertification, the case of Sudan. J. of Basic science, Sudan institute for natural science, Vol.6 55-68.

Lange, S. (2006): Benefit streams from mining in Tanzania: Case studies from Geita and Mererani - 2006 - open.cmi.

Ministry of Energy and Mining (2017): Sudan Mining Code, A Guide for Reporting and Exploration Results, Mineral Resources, Ore Reserves and mining activity in the Sudan.

Naicker, K., Ckrowska,E. (2003): Acid mine drainage arising from gold mining activity in Johannesburg, South Africa and environs. In Environmental pollution, 122(1):29-40, Feb. (2003). DOI: 10.1016/S0269-7491(02)00281-8.

Salah, M and Elli, E (2020): How Sudan's gold boom is changing labour relations in Blue Nile State. Rift Valley Institute Briefing Paper.

Singo, P. and Seguin, K. (2018): Best practices: formalization and due diligence in artisanal and small-scale mining. IMPACT transforming natural resource management. ISBN: 978-1-897320-39-6**.**

SMRC, (2017): Unpublished report.

Sudanese Mineral Resources Company SMRC (2017): Requirements and Guidelines on Health, Safety and Environment Management System.

Sonter, L.J., Herrera, D., Barrett, D.J., Galford, G.L, Moran, C. J., & Swarez, B.S. (2017): Mining drives extensive deforestation in the Brazilian Amazon. *Nature Commun* 8, 1013 https://doi.org/10.1038 /s41467-017-00557-w

Telmer K.H., Veiga M.M (2009): Mercury Fate and Transport in the Global Atmosphere. Springer; Heidelberg, Germany: 2009. World emissions of mercury from artisanal and small scale gold mining; pp. 131–172. [Google Scholar]

Tolentino, A.S., Badi, K., El Hori, A., and Bayoumi, A. M (1994): Environmental Legislations and Institutions in the Sudan.fao.org/3/xii/0873-c1.htm.

Vureen, L. (2009): Coal mining impact on Waterberg under the microscope: Project watch. Journ. of water wheel, vol. 8, Issu. 2 (2009), p 14-15.

WHO (World Health Organization) (2006): Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Third Edition of Wastewater Reuse Guidelines. http//www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html

WHO, (2016): Environmental and occupational health hazards associated with artisanal and small-scale gold mining. ISBN 978 92 4 151027 1 (NLM classification: WA 485)