# Properties and Applications of Sepiolite Clay Mineral from El-Bur, Gal-Mudug Regional State, and its potential role for Somalia's long-term Economic Development

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# Glossary of Somali Terms

| | |
|---|---|
| **Bali** | A natural depression on flatter silt soils that collect surface runoff with water-holding capacity. |
| **Berkad** | A concrete-lined reservoir roofed with small bushes suspended over the tanks with nets. |
| **Burjiko** | Charcoal-burning stove made from Sepiolite clay mineral mined from El-Bur. |
| **Dabqaads** | Somali-style fire raiser with either one or two handles made from Sepiolite clay mineral in El-Bur used to perfume homes after meals and during special occasions by using Frankincense (lubaan) or prepared incense (uunsi). |
| **Deyr** | October to November, minor wet season |
| **Gu** | April to June, major wet season |
| **Hagaa** | July to September dry and cool season |
| **Jilaal** | Dry season from December to March |
| **Wadaan** | Wadaan is a skin-bucket made by skin of goats or sheep with long rope attached to its mouth and is used to lift up extracted wet Sepiolite clays or water from bottom of wells tossed from man to man in a human chain. |

# List of acronyms

**AVHRR** Advanced Very High Resolution Radiometer

**DTA** Differential Thermal Analysis

**EM** Electron Microscopy

**GP** Growing Period

**IR** Infrared Absorption

**NDVI** The Normalized Difference Vegetation Index

**NIR** Near-infrared wavelength

**NOAA** National Oceanic and Atmospheric Administration (NOAA) satellites.

**VIS** Visible wavelength

**XRD** X-ray diffraction

# Summary

The main objective of this study is to investigate the nature and characteristics of Sepiolite clay mineral in El-Bur and to explore its economical benefits for Somalia's long-term economic development. A large Sepiolite deposits which has an estimated total of 100 metric ton (Mt) occur in El-Bur city in Gal-Mudug region of Somalia though is used mainly to manufacture cooking stoves and handcrafted souvenirs. The deposits are surface mined and dry processed to produce charcoal-fired cooking stoves (Burjikos), Dabqaads and ashtrays to avoid smoke odour and decorative carvings and are sold in Somalia's markets and neighboring countries. The produced Sepiolite clay mineral in El-Bur contribute a livelihood for many people who are involved in the mining, production, transportation, and marketing of these mineral clays. Although it will undeniably require deeper reforms and implementation of effective strategies intended to make the mining sector in Somalia a key player in economic transformation, the Sepiolite mining industry in El-Bur could offer unparalleled opportunities for both local and international investors seeking expansion to new markets in Somalia.

Results suggest that Sepiolite has an immense industrial uses which people in Somalia do not benefit it, but if well developed and properly managed, El-Bur's Sepiolite mineral endowments and other precious minerals in the city such as uranium could help lifting Somalia out of poverty and catapult it to growth, development and prosperity. Moreover, this pure Sepiolite deposits will attract more foreign investors in the future and revenues generated could help Somalia's economic development and achieve greater economic diversification. Sepiolite is extremely rare and voluble clay mineral due to its peculiar characteristics and has the potential of contributing significantly to poverty reduction and social and economic empowerment of the population. Therefore, in order to unlock its mining potential, Somalia should overcome the hindrances that hamper the development of its mining industry.

The study concludes that markets for Sepiolite will continue to expand and its demand will increase in the future because of its special sorptive and catalytic properties which are the basis for many technological applications. Furthermore, the linkages between Sepiolite mining in El-Bur and the national economy could only be enhanced through capacity building to mining workers, manufacture of mining inputs, and provision of enhanced security. In order to maximize Sepiolite economic benefits for the country and to ensure the greatest possible benefit for the public, the Federal Government of Somalia and Ministry of Petroleum and Mineral Resources in particular are advised to create innovation and knowledge based culture through skills development and support infrastructure and to build the capacity of Sepiolite miners in El-Bur and while simultaneously encouraging investment in the mining sector.

# 1. Introduction

In spite of its abundant natural resources, Somalia is characterized by high levels of poverty and political instability. The country is endowed with enormous natural resources such as livestock, precious minerals, agricultural land, marine resources, frankincense and likely deposits of petroleum and natural gas (Appendix 4) that can be profitably marketed both domestically and internationally. Although the country has the above-mentioned natural resources, the full potential of Somalia's natural resource wealth remains unexplored and untapped due to the lack of strong functioning government across the country. While it is virtually inarguable that natural resource reserves can offer substantial economic benefits to Somalia, unfortunately this potential often goes unrealized. But, if properly developed, these natural resources could offer great opportunities for achieving high levels of economic growth and development for the country. Even though the minerals industry makes a small contribution to the Somalia's exports and the economy in general, the country has been known to produce small quantities of gypsum, salt, and Sepiolite (Appendix 5). It is also believed to have large deposits of feldspar, iron ore, kaolin, limestone, quartz, uranium and natural gas (Chakrabarti, 1988).

Prior to the collapse of the Somali government in 1991, the country's major employment source was coming from the national government. But, with the fall down of the state, the greatest impact of unemployment was felt across Somalia in particular in the Southern part of the country where most government institutions were based. However, during the civil unrest of Somalia, El-Bur was one of the very few places where its people had the opportunity to go mining for their livelihood in the entire country of Somalia. The craftsmen in the city have been manufacturing the Somali charcoal-fired cooking stove made of crafted Sepiolite clay mined in the South-West of El-Bur (Figure 4-1). Mining of Sepiolite in El-Bur was traditionally practiced over the years producing charcoal-fired cooking stoves and decorative carvings that are sold in the Somali markets as well as neighboring countries. Although the mineral potential in El-Bur was neither adequately explored nor surveyed properly, it is believed the city remains to be one of major areas that will offer opportunities to companies that venture into Somalia for mineral explorations. The city has large deposits of Sepiolite which is estimated about 100 metric ton (Mt). The Indho-Qabyo prospect for instance is estimated to have resources of 19 Mt of Sepiolite (Chakrabarti, 1988).

To date, however, little attention has been given to address the importance of Sepiolite mineral in El-Bur. As a result, the main objective of this study is to investigate the nature and characteristics of Sepiolite clay mineral in El-Bur and to explore its economical benefits for Somalia's long-term economic development. This study work is researching and combining data to create a suggestions and recommendations of the potential El-Bur's Sepiolite mineral resources for the Somali economy. The study is based on a wide range of secondary data sources, such as available academic literature, databases, and policy reports. In addition, contacts were established with different local inhabitants in El-Bur to explore further information related on Sepiolite mining and the study area in general.

Despite the shortcomings in available data, the findings of this study reveals that Sepiolite has an enormous industrial uses which Somalis do not benefit them, but in the future this pure Sepiolite deposits will attract more investments. High-quality quality stones of Sepiolite can be used in manufacturing of pipe and ornament goods, whereas waste and low quality stones are consumed as pipe lining (Hande & Mizam, 2011). Interestingly, one of the more important uses of Sepiolite is in drilling fluids, where both the viscosity and the gel strength of the mud are not affected by variations in electrolyte content as are drilling muds in which bentonite is used (Galan (1996). Sepiolite drilling muds can be used with salt water when formation brines become a serious problem. It can also be used for other purposes such as pet litters due to its light weight, high liquid absorption and odour control characteristics (Galan, 1996). Sepiolite absorbs pet urine and has a dehydrating effect on solid faeces which minimizes bad smells and hampers bacteria proliferation. In construction, Sepiolite can be used in lime mortars as water reservoir (Hande & Mizam, 2011). The concrete specimens made with Sepiolite wastes are lighter than the specimens made with concrete. The usages of light weight concrete become more popular especially in Belgium, England, and Germany, Netherlands and the U.S.A (Hande & Mizam, 2011).

it is essential to point out that El-Bur was once served as a local commercial hub in central regions of Somalia, but the city has lost its population and commerce due to lack of passing highways. Since the independence of the country, the city inherited a poorly developed transportation systems consisting of a few unpaved roads. The Gal-Mudug region has only one major paved road that extends from South-west to North-west of the region. But, all other links to eastern part of the region including El-Bur are unpaved roads which makes difficult to use during the rainy seasons. With the collapse of the government in 1991, the city had been reduced to rubble, with government buildings, schools and hospitals either destroyed or looted. The city has relatively enjoyed stability since that period though some sporadic clashes have occurred in the rural areas for fight over water and pasture. Since 2006, El-Bur has been long served as largest remaining stronghold of Al-Shabab militant group in central Somalia before the Somali government forces and the Ethiopian troops captured the city in early 2014, though the war is still being waged in the rural areas of the city that resulted in extreme hardship to the people.

# 2. Study area

## 2.1 Topography

El-Bur is a district located in Gal-Mudug Regional State in central Somalia and is known to be one of the oldest cities in the country. It is situated 360 km North West from Mogadishu and between latitude 4.68501 and longitude 46.6176 in decimal degrees with an average elevation of 175 meters above sea level (Figure 2-1).

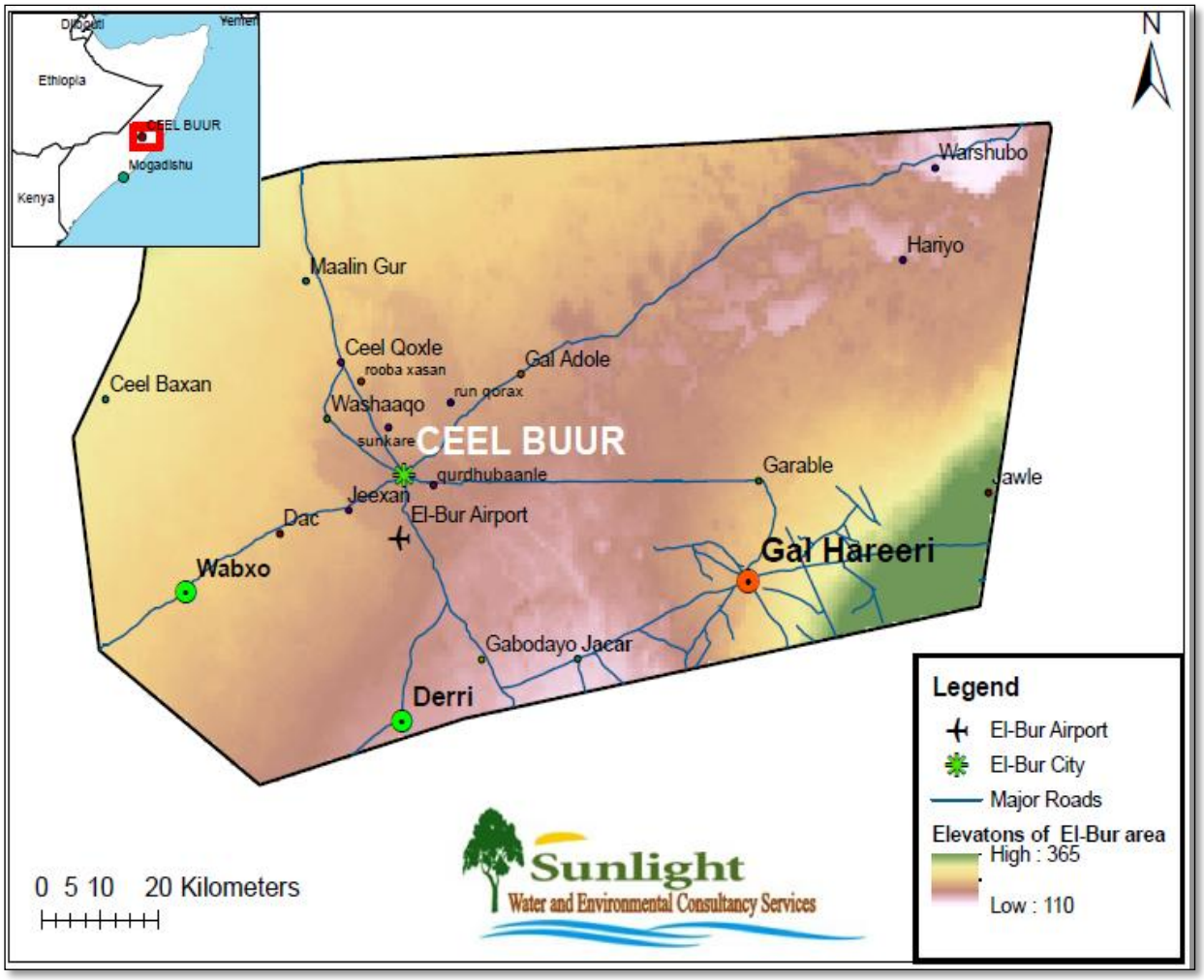


**Figure 2-1 a map showing the location of El bur City and surrounding areas.**

The El Bur area is situated in the central plateau that, with an area of 150,000 km$^2$, constitutes one-fourth of the Somalia's surface (Singer & Stahr, 1998). The physiography of the area is nearly level to slightly undulating, with shallow depressions that have playa-like characteristics and frequently contain saline lakes of a seasonal nature. The area belongs to the 'southern gypsum' division of the Taleh formation (Watson*et al.,* 1982). The Sepiolite deposits are situated about 4 km South-West of the city.

## 2.2 Climate

El-Bur is located in an arid and semi-arid climate region. Like the rest of other regions in Somalia, the rainy seasons of the El-Bur are Gu and Deyr, whereas Hagaa and Jilaal mark the dry seasons. The Gu season runs from April to June and is with about 60 % of the annual precipitation in the major rainy season for the study area. The Deyr season lasts from October to November and amounts less than 30 % of the annual precipitation. Jilaal is the first dry season of the year lasting from December to March causing very hot and dry conditions. Hagaa, the second dry season runs from July to September causing dry and cool conditions with some littoral showers. Summary of main characteristics of four Seasons in Somalia are presented in Table 2-1.

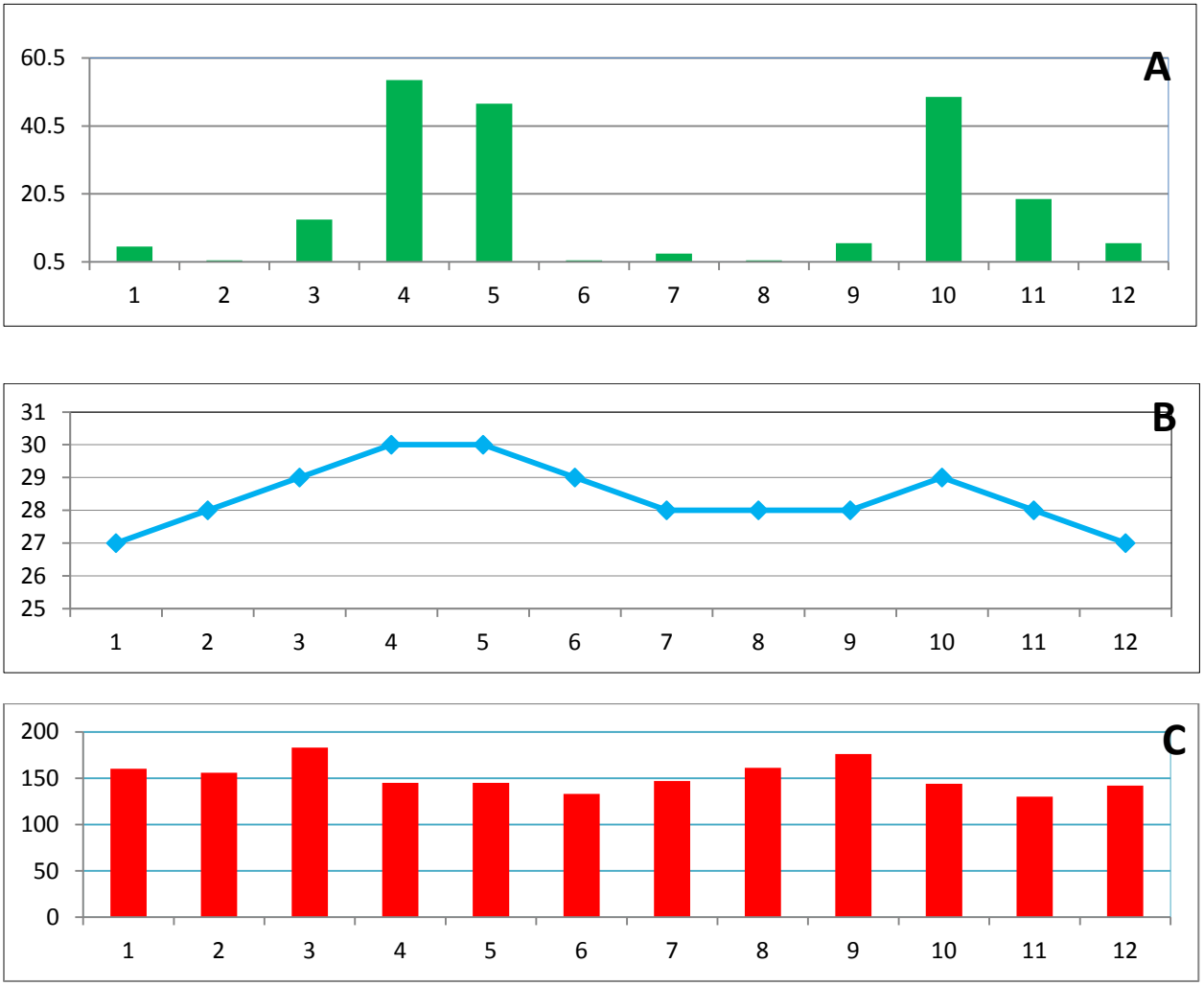


**Figure 2-2 Mean monthly precipitation (a), temperature (b) and potential evaporation (c) for El-Bur for the period 1961-1990. The month is given as an integer, ranging from 1 (January) to 12 (December).**

**Table 2-1 Summary of main characteristics of four Seasons in Somalia, based on [Oduori et al., 2007]**

| Season | Jiilaal | Gu | Xagaa | Deyr |
|---|---|---|---|---|
| **period** | Jan/Feb/ Mar | Apr /May/ Jun | Jul /Aug /Sep | Oct /Nov /Dec |
| **Characteristics** | Long dry season, hot or very hot | Main rainy season | Cool and cloudy, littoral showers, dry and cool in hinterland | Second rainy season |

Rainfall in El-Bur area is low and erratic with mean annual rainfall of 205 mm/year (Figure 2-2a). Temperatures in El-Bur varies with the seasons, with mean annual temperature of 28°C, with a maximum temperature of 43°C in March and a minimum temperature of 23°C in July (Figure 2-2b).The potential evapotranspiration of the study area is also high throughout the year (Figure 2-2c).

## 2.3 Land cover and Land use

The land cover in the study area consists mainly of grassland, shrubland and rainfed crops (Figure 2-3). The typical agricultural products grown in the area include sorghum, beans and white-watermelon. The agricultural production in the study area is extremely low due to the sparse precipitation and as a result, most of the attention has been paid to crops with a short Growing Period (GP). The other cover types in the study area include urban and associated areas, sand dunes and bare lands. Woody and herbaceous species such as *Acacia tortilis, and A. seyal* were also found in the study area (Singer & Stahr, 1998).

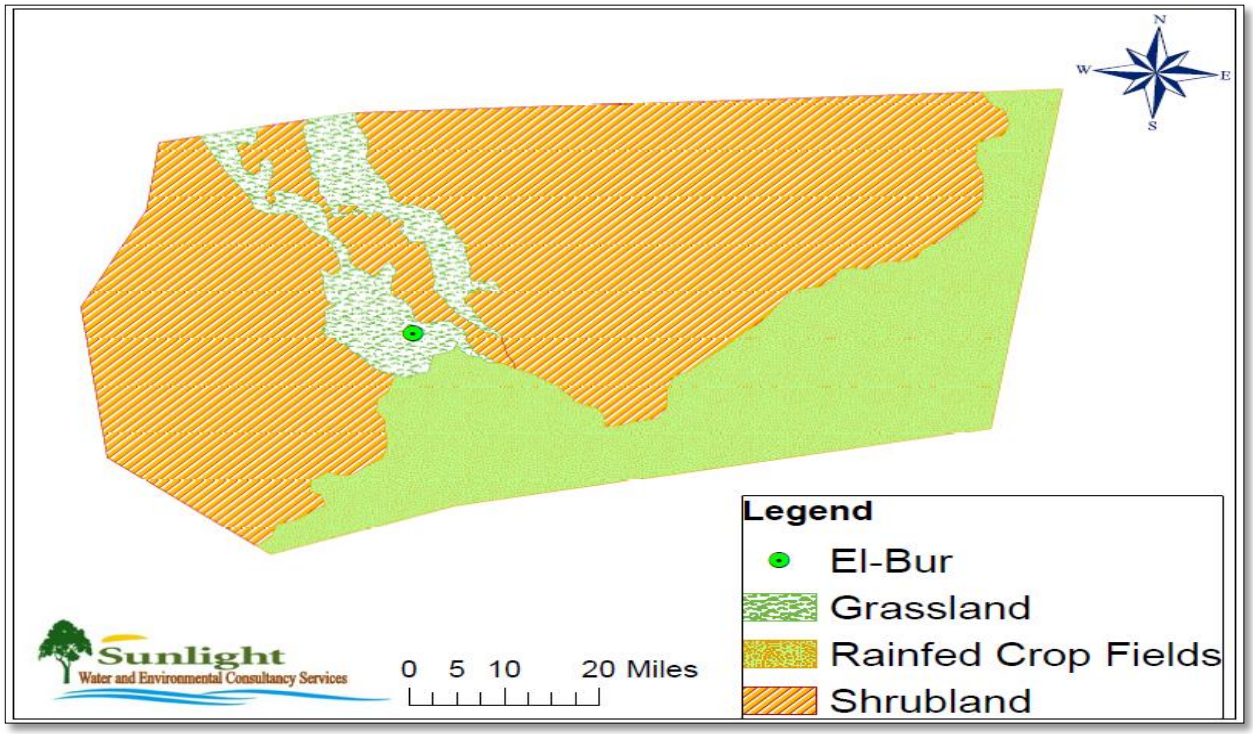


**Figure 2-3 land cover of the study area**

On the other hand, the land use in the study area is mainly livestock grazing and wood collection for fuel and building material. Rangelands in the study area support livestock such as goats, sheep, and camels, horses (which is a central part of El-Bur identity). Rural communities in these areas are sedentary, practicing animal husbandry in conjunction with some rainfed crop production in South-East of El-Bur (Figure 2-4). They tend to keep lactating animals near their areas while non-lactating animals are herded further away in the manner of herding nomadic stock. Annual grasses provide some meager pasture for the livestock of the partly nomadic population (Singer & Stahr, 1998). It is also interesting to note that the camel plays a central role in social life in the study area as an indicator of wealth and success. In generally, camels could normally survive in an environment where water and grazing areas are scarce and widely scattered such as Gal-Mudug region where there are no perennial rivers like the Juba-Shabelle basin in southern Somalia.

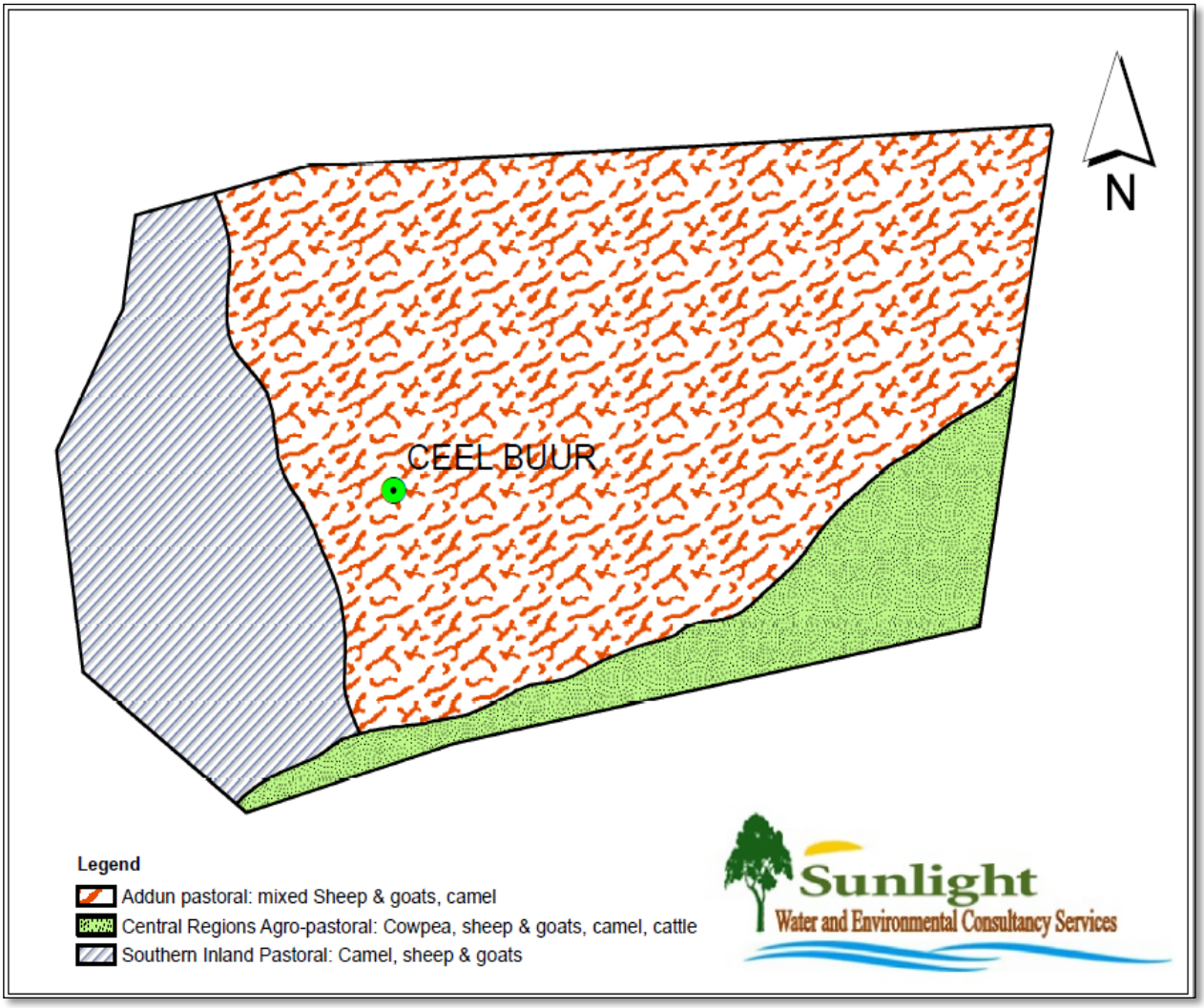


**Figure 2-4 Field economy of the study area (distribution of livestock).**

## 2.4 Soils

The main soil types in El-Bur area are Calcaric Arenosols, Calcaric Cambisols Haplic gypsisols and Petric gypsiols (Figure 2-5). The central part of Somalia covering the Ogaden drainage basins is dominated by moderately deep loamy soils with a high content of calcium carbonate and gypsum further inland in Elbur areas. in addition, the soils are moderately to highly saline and contain Sepiolite in their clay fraction (Drechsel, 1991). But further in the east of the city is dominated by sandy soils.

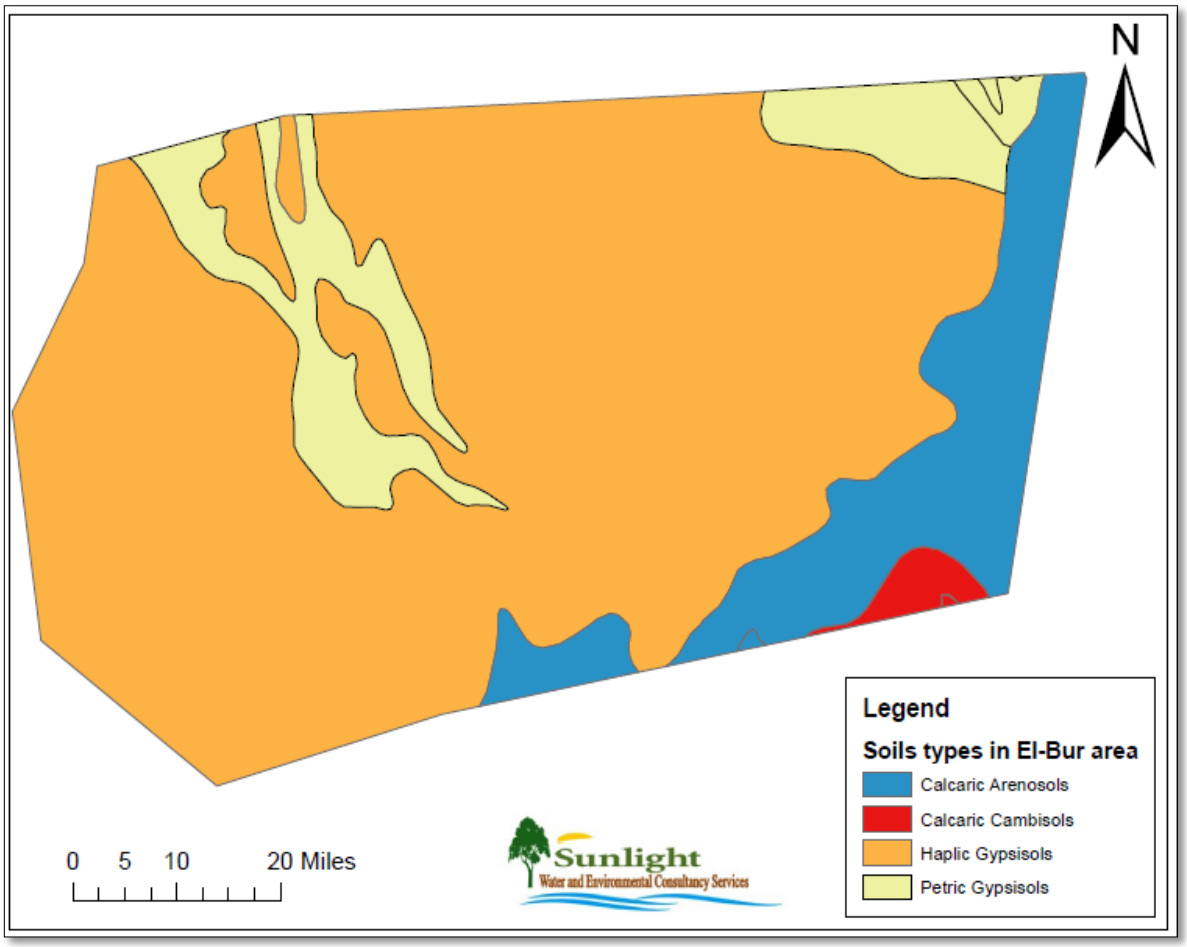


**Figure 2-5 Soil types of El-Bur and the surrounding areas.**

## 2.5 Geology and landscape

In East Africa, the regional geology consists of a Precambrian basement overlain by a thick succession of Jurassic to Quaternary sediments which attain a thickness of about 7000 m in the Somalia basin in the Gal-Mudug Province. Major portion of the Somalia peninsula constitutes a wide sedimentation basin, into which a sequence of marine transgressions from the North East towards the South West deposited huge sedimentary formations, beginning with the Jurassic and

continuing into the Upper Tertiary (Singer & Stahr, 1998). While Palaeozoic rocks apparently are absent, sandstone from the Triassic has been found only in Northern and Southern Somalia. El-Bur is particularly distinguished as a center for quarrying which has large deposits of pure Sepiolite. The deposit is associated with lower to Mid-Eocene Taleh Formation that includes limestone, dolomite and gypsiferous marls, extensive anhydrite and various evaporates, primarily gypsum (Singer & Stahr, 1998). Detailed lithology of the study area is shown in Figure 2-6.

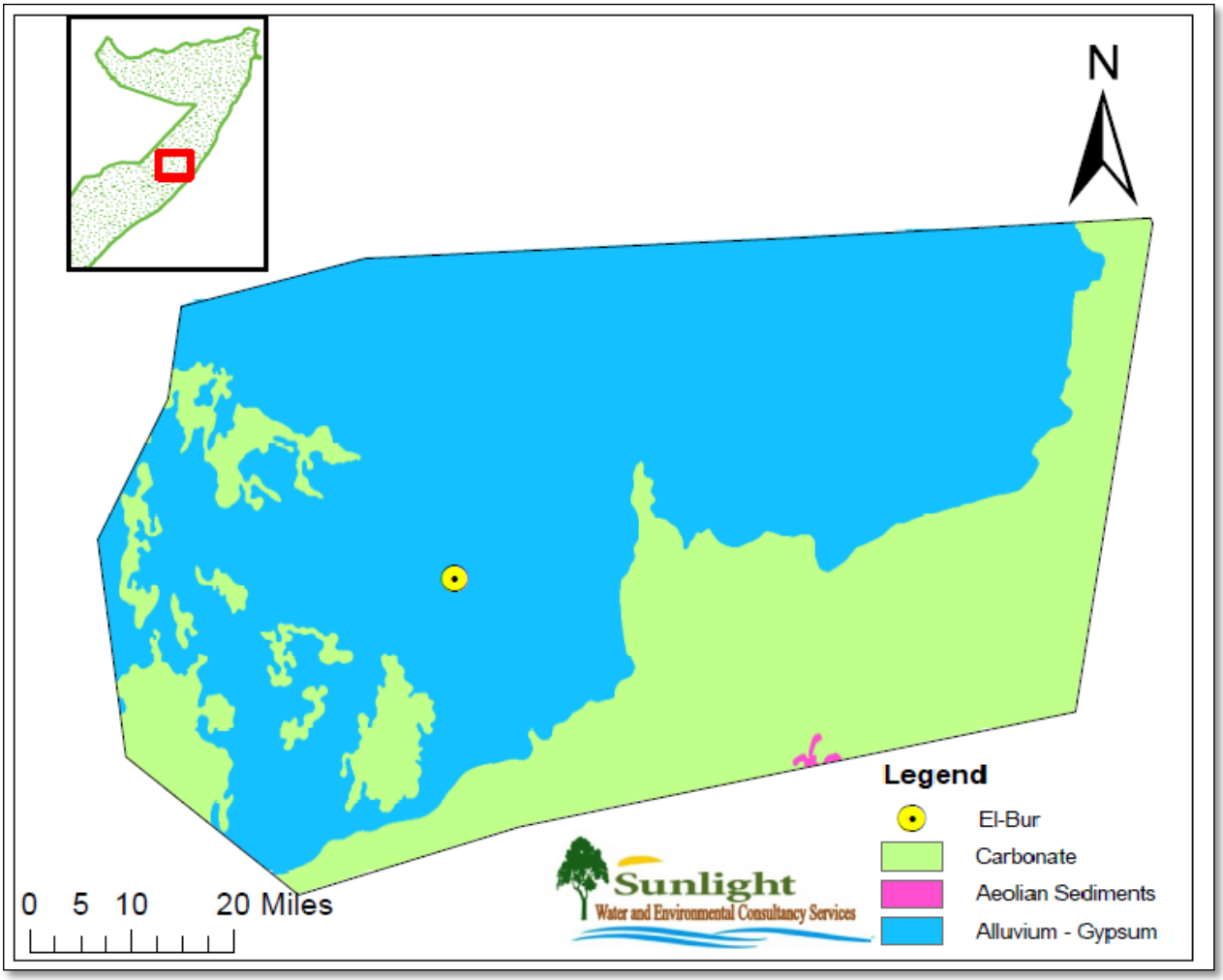


**Figure 2-6 Detailed lithology of El-Bur in Gal-Mudug region in central Somalia.**

Furthermore, exposures of crystalline basement rocks are known only from the El-Bur city in Central Somalia, and in Northern Somalia (Singer & Stahr, 1998). Evaporates, particularly gypsum, are abundant in the surface sediments and occur in a variety of forms. The abundance of evaporates indicate a lacustrine, closed basin evaporative environment. These sediments are in accord with the present climate, which is semi-arid to arid and thus may have formed contemporaneously (Singer & Stahr, 1998). .

## 2.6 Hydrology

### 2.6.1 Surface Water Storage

Natural water ponds (balleys) or small depressions that contain water are common in El-Bur areas. These areas include Shakalego , Reydaab, Qudhale, Balley Dheere , War Dararow , Qori, Dab Dhamag, Dab Hoolo, Miir Halane, Magay, Sarman Lidanyo, Garas Dabaken, Hin Jika Weyne, Wiidi. The water ponds in these areas are mainly used for rain water harvesting and utilized by both rural populations and the animals. Flooding may occur, with the water accumulating in shallow depressions, but due to the high rate of evaporation in the study area, surface waters disappear quickly.

In general, Somalia can be divided into nine major drainage basins: Gulf of Aden basin, Darror basin, Tug Der/ Nugal basin, Ogaden basin, Shabelle basin, Juba basin, Lag Dera basin, Lag Badana basin and Central Coastal basin (Figure 2-7 and Table 2-2). The Juba and Shabelle are the only two perennial rivers in Somalia where there is a flow throughout the year. Other drainages have surface water only after periods of heavy rainfall (Basnyat, 2007).

**Table 2-2 Catchment Areas of Major River Basins in Somalia (Basnyat, 2007).**

| | catchment Area | | |
|---|---|---|---|
| **Major Drainage basin** | **Total ($km^2$)** | **Within Somalia ($km^2$)** | **% of total** |
| Juba | 220,872 | 64,744 | 29% |
| Shabelle | 296,972 | 108,295 | 36% |
| Lag Dera | 231,639 | 46,335 | 20% |
| Lag Badana | 16,575 | 16,575 | 100% |
| Ogaden (Central) | 234,943 | 159,500 | 63% |
| Tog Der/Nugal | 112,231 | 112,231 | 100% |
| Darror | 34,195 | 34,195 | 100% |
| Gulf of Aden | 74,422 | 74,422 | 100% |
| Central Coastal | 27,638 | 27,683 | 100% |

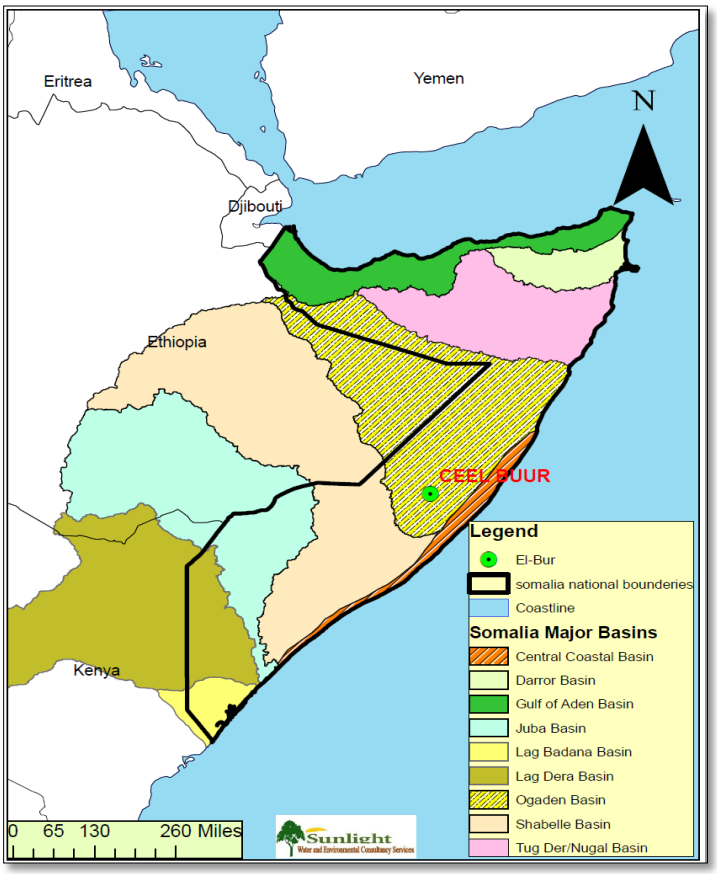


**Figure 2-7 Catchment Areas of Major River Basins in Somalia**

El-bur is however belongs to the Ogaden drainage basin which is one of the main nine drainage basins in Somalia and has high percentage of rainwater ponds which might indicate the inadequate groundwater potential in these areas (Basnyat, 2007). As the area is mostly arid, with the least developed drainage network, localized runoff occurs during high rainfall but quickly dissipated through evaporation and infiltration ( Appendix 3).

### 2.6.2 Groundwater of the study area

Groundwater is an important source of water to meet the needs of the human and livestock populations in El-Bur and Gal-Mudug province in general. Unfortunately, there are no data available on either groundwater occurrence or abstractions. The rates of groundwater recharge are also not precisely identified. But the recharge is known to occur through infiltration from direct precipitation and percolating surface water from the balleys or other water ponds in the area.

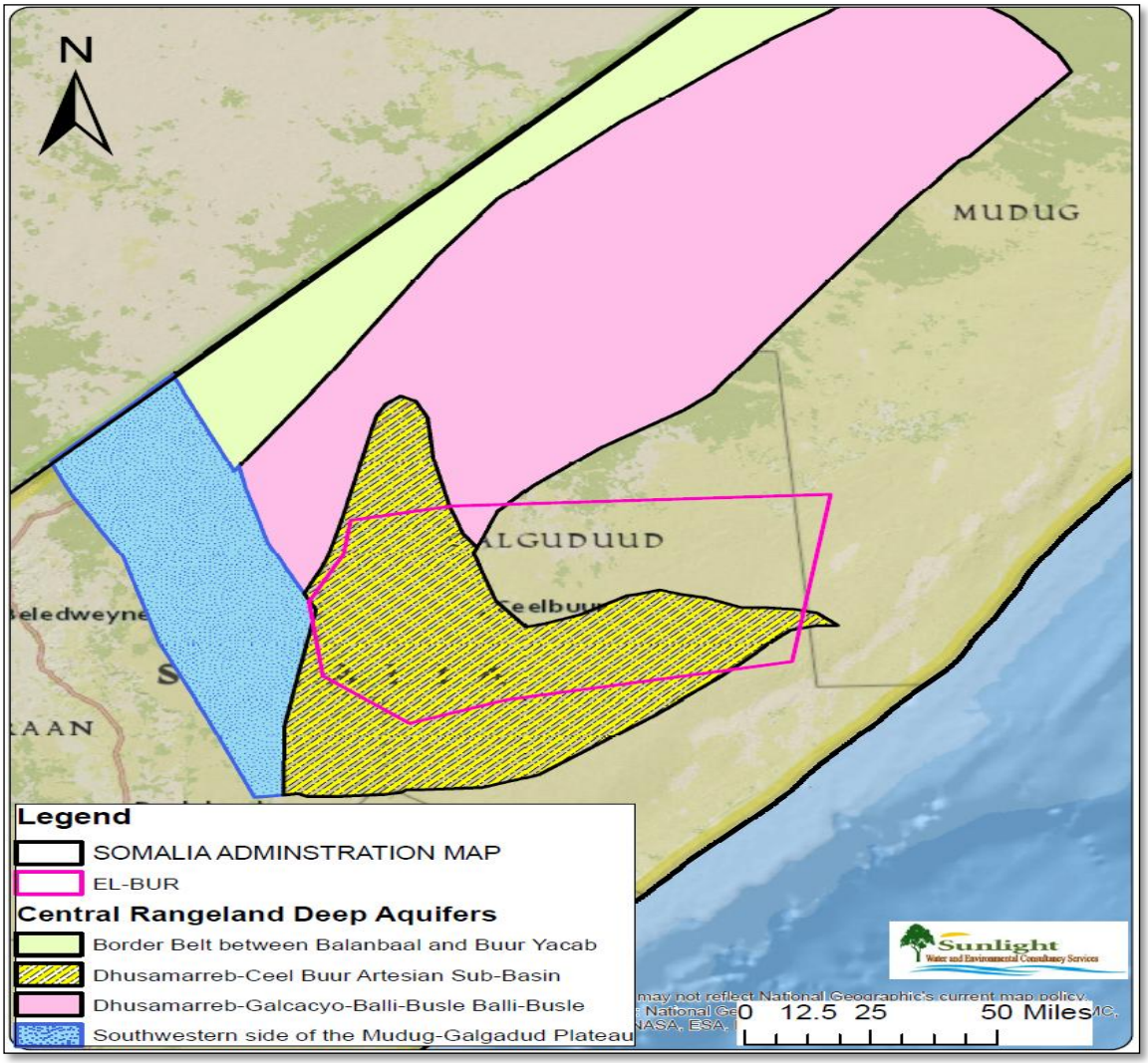


**Figure 2-8 Central Rangeland Deep Aquifers in Central Somalia.**

Shallow wells are also the common sub-surface water sources in EL-Bur. These wells are typically unlined, open with logs and stone arranged around the mouth. The dug wells are mainly utilized in the rural areas and the urban populations have a balanced usage of the shallow wells and boreholes. However shallow wells are known to have high organic contamination due to poor construction and common outlets for both livestock and humans and many of them run dry during prolonged droughts (Basnyat, 2007). It is important to note that there are a number of wells in the area that can supply sufficient quantity of water throughout the year. Cehan (Jeexan ) Shallow well for instance, which locates 17.3 km South-West of El-Bur can supply water throughout the year for drinking water and animals watering. Jeexan was a transfer camp for drought affected people from North and Central regions of Somalia in 1977 before airlifting them to southern part of the country particularly in Sablale, Dujuma and Kunt-warey.

**Table 2-3 Areas with good Groundwater Potential in the Ogaden Drainage Basins in Gal-Mudug province (Basnyat, 2007).**

| No | River Basin | Region | District | EC range ( uS/cm) | Well Depth (m) | Remarks |
|---|---|---|---|---|---|---|
| **Southern Side of the Galgudud-Mudug Plataea** | Ogaden | | Abudwaq, Galkacyo, Goldogob | N/A | 100-220 | Yasoomman formation constituted by red sand and sand stone covering a large belt of 30-60 km along the western side of the Galgudud-Mudug- basin |
| **Border Belt between Belanbal and Bur yaqab** | Ogaden | Galgudud | El-Bur | 1750-3000 | 120-250 | unconfined aquifers with water level between 75-150 m |
| **Dusamareeb-Galkacyo-Balli Busle** | Ogaden | Galgudud-Mudug | Dusamareeb, Adado Galkacyo | N/A | 150-200 | |
| **Dusamareeb-El-Bur artesian sub-basin** | Ogaden | Galgudud | El-Bur Dusamareeb | N/A | N/A | deep aquifers overlain by basalt has high artesian pressure and well production is good, wells in El-Bur can be used for scale small irrigation |

Faillace and Faillace (1987) suggested areas that have good potential for groundwater development across Somalia based on hydro-geological and water quality suitability using data collected from wells. The areas with good groundwater potential in the Ogaden drainage basin in central Somalia are given in Figure 2-8 and Table 2-3. On the other hand, there is high salinity that poses serious threat to the quality of groundwater in the study area which results from water logging of salinized soils due to dissolution of salts in the sediments and evaporation under the arid conditions. This problem affects the groundwaters in large parts of central and North-western part of the study area Figure 2-9). Dryland salinity has long been a threat to the land and water resources in large parts in

El-Bur though only in recent years has the seriousness of the problem become widely recognized. The excess salinity in groundwater has long been the cause of health problems, destruction of fertile agricultural lands, and damage to eco-systems of the area. Despite these areas are far from the ocean, the elevated sodium levels in groundwater can come from erosion of salt deposits and sodium bearing rock minerals or it could be naturally occurring brackish water of some aquifers.

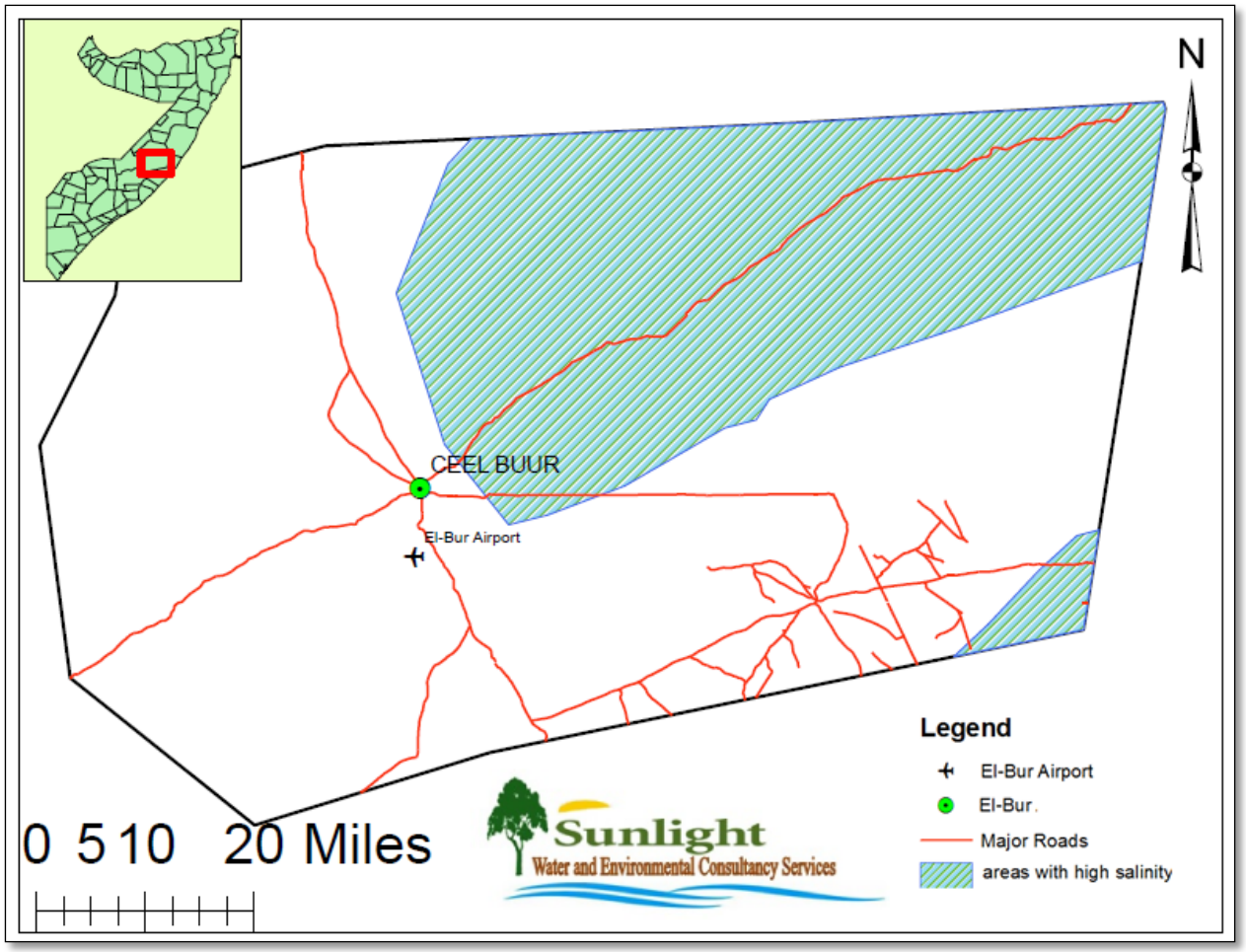


**Figure 2-9 Areas with high Salinity in EL-Bur in Central Somalia.**

# 3. Methods

El-Bur has a long tradition of Sepiolite mining and its mining practices would remain common in this city as it contributes a livelihood for many people involved in the production, transportation, and marketing of Sepiolite clay minerals. For well over a century, the Sepiolite mining has taken place in El-Bur as from the evidences of history of the city and its mining descriptions suggest. To date, however, little has been written about Sepiolite mineral resources in this city. Therefore, in order to acquire adequate and accurate assessment, it would require comprehensive and detailed assessment to be carried out. But, due to wide insecurity in the study area, it was impossible for the author of this study to visit El-Bur to carry out in-situ assessment. The methodology followed in this paper is simple and was focused on the properties and characteristics of Sepiolite mining in El-Bur, and with an emphasis on how this clay mineral better contributes to Somalia's long-term economic development.

This study work is therefore researching and combining data based on a wide range of secondary data sources, such as available academic literature, databases, and policy reports. It was also used GIS (geographical information system) tool to produce a wide range of different maps of the study area and NDVI (The Normalized Difference Vegetation Index) to scrutinize the scale of vegetation loss in the study area. The magnitude of NDVI is related to the level of photosynthetic activity in the vegetation being observed and is derived from data collected by National Oceanic and Atmospheric Administration (NOAA) satellites. It is calculated from two channels of the AVHRR sensor, the near-infrared (NIR) and visible (VIS) wavelengths, using the equation (1).

$$NDVI = \frac{NIR - VIS}{NIR + VIS} \quad (1)$$

Where *NIR* is the near infrared channel of the electromagnetic spectrum and VIS is the visible channel. NDVI is a nonlinear function that varies between -1 and +1 (undefined when NIR and VIS are zero). In general, higher values of NDVI indicate greater vigour and amounts of vegetation. Furthermore, contacts were established with different local residents in El-Bur to explore further information related on Sepiolite mining and the study area in general. The obtained data was selected based on its reliability, robustness and immediacy.

# 4. Results

## 4.1 Characteristics and properties of Sepiolite

Sepiolite (formerly known as Meerschaum) is a white claylike mineral of hydrous magnesium silicate that has an irregular and white colored crystalline structure. The name of Sepiolite originates from a perceived resemblance of the material to the porous bones of the cuttlefish or sepia. Abrahan Gottlieb Werner was originally named meerschaum in 1788, and later translated as *l'Ecume de mer*. In 1794, the mineral was called keffekill by Richard Kirwan. in 1807, Alexandre Brongniart called this mineral magnesite (Hande & Mizam, 2011). Ernst Friedrich Glocker named from the Greek, "sepion," cuttle-fish bone in 1847, because of its low density and porous bone like appearance (Hande & Mizam, 2011). Sepiolite is non-swelling, lightweight, porous clay with a large specific surface area. It is a wet and moisturized under soil which makes it simple to process after extraction from the mining pit. Scientifically, Sepiolite is represented by the formula $Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$ and is used as adsorption means for many liquids such as drilling muds, paints, liquid detergents, adhesives, car polish, flexiographic inks, cosmetics, floor absorbents, potting mixes, oil-spill cleanup material.

Sepiolite is extremely uncommon clay mineral due to its strange characteristics and rare occurrence. According to Hande & Mizam, (2011), Sepiolite can be found in the nature in two different forms. The first one is known as α-Sepiolite which is shapeless, in compact state, and in the form of pellets which looks like see froth. The other type is β-Sepiolite which can be found in the form of amorphous aggregate or small flat and round particles (Hande & Mizam, 2011). These two forms differ from each other according to the physical properties. Some prominent properties of Sepiolite are tabulated in Table 4-1.

**Table 4-1 Properties of Sepiolite clay mineral in the nature (Altun et., 2015)**

| Particle Structure | Fibrous |
|---|---|
| **Mohs's Harness** | 2.0-2.5 |
| **High Surface Area** | 150-320 $m^2/g$ |
| **Cation exchange capacity** | 30-50 meq/100g |
| **Melting point** | 1550 °c |
| **Water absorption** | Wide |
| **Oil absorption** | Up to 80% of its weight |

## 4.2 Production of Sepiolite in El-Bur

There are virtually pure Sepiolite deposits in a playa-like depression in approximately 4 km South-west of El Bur. The deposits are associated with the Lower to Mid-Eocene Taleh Formation that includes dolomite, limestone, gypsiferous marls, extensive anhydrite and various evaporites, primarily gypsum (Singer & Stahr, 1998). Stahr *et al.* (1990) presented comprehensive description of

a Sepiolite occurrence in El-Bur. They described it a material extracted and worked by local inhabitants in El-Bur, which produced ceramic and popular art objects from the raw clay. The geomorphological setting of the El-Bur Sepiolite is to similar to that of the Tertiary lacustrine basins in Spain and Turkey (Galfin & Castillo, 1984; Doval *et al.,* 1986). Results indicate that, to a depth of 3 m at least, massive Sepiolite is present at the surface sediments in El Bur (Stahr & Zarei, 1998). However, in the absence of detailed prospecting, the vertical and lateral extent of this deposit is yet to be identified. Singer & Stahr (1998) carried out chemical analysis on samples taken from El-Bur Sepiolite mining site using XRD, DTA, IR and EM. The XRD and DTA analyses indicated that from 40 cm down to a depth of 300 cm, the material consists of well crystallized Sepiolite, accompanied in some layers by minor calcite and traces of quartz and halite (Singer & Stahr, 1998). Table 4-2 presents chemical composition from a Sepiolite excavation pit in El-Bur. The data indicates Al, Ca, Na, K, Fe and Ti (expressed as oxides) are present only in very small amounts in all the layers examined. All layers in the excavation pit except at 100-200 cm contain some impurities. Layers at 40-100 cm and 200-300 cm contain some halite, whereas, layers at 0-40 cm and 200-300 cm also contain calcite.

**Table 4-2 Chemical composition (%) of fine earth (<2 mm) and clay (<2 µm) from a Sepiolite excavation pit in E1-Bur, Central Somalia (Singer & Stahr, 1998).**

| Layer (cm) | 0-40 | | 40-100 | | 100-200 | | 200-300 | |
|---|---|---|---|---|---|---|---|---|
| | <2mm | <2µm | <2mm | <2µm | <2mm | <2µm | <2mm | <2µm |
| **$SiO_2$** | 46.6 | 52.2 | 50.2 | 56.7 | 58.6 | 54.0 | 46.0 | 47.7 |
| **MgO** | 9.40 | 15.2 | 18.7 | 20.8 | 20.2 | 19.5 | 16.3 | 15.7 |
| **$Al_2O_3$** | 2.80 | 4.08 | 0.90 | 1.00 | 0.80 | 0.83 | 0.74 | 1.30 |
| **CaO** | 14.5 | 9.00 | 0.50 | 1.30 | 0.80 | 0.83 | 10.6 | 5.20 |
| **$Na_2O$** | 0.94 | 0.03 | 3.70 | - | 0.41 | 0.07 | 3.60 | 0.23 |
| **$K_2O$** | 1.04 | 1.10 | 0.46 | 0.47 | 0.74 | 0.03 | 0.42 | 0.63 |
| **$TiO_2$** | 0.30 | 0.40 | 0.11 | 0.12 | 0.54 | 0.40 | 0.09 | 0.18 |
| **$Fe_2O_3$** | 1.46 | 2.46 | 0.59 | 0.50 | 0.11 | 0.10 | 0.37 | 0.78 |
| **MnO** | 0.01 | 0.02 | - | - | 0.39 | 0.48 | 0.02 | 0.07 |
| **$P_2O_5$** | 0.02 | 0.03 | - | 0.04 | - | - | - | 0.05 |
| **ZrO** | 0.03 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 |
| **$H_2O(+)$** | 12.0 | 10.0 | 11.0 | 16.0 | 8.00 | 19.0 | 14.0 | 21.0 |
| **$H_2O(-)$** | 10.9 | 5.40 | 13.8 | 3.00 | 10.1 | 5.60 | 7.70 | 7.20 |

In El-Bur, The Sepiolite clay minerals are extracted from two major areas namely Kawo El-dher and Kawo Saudi that are situated in Southwest of the city. However, miners often use inappropriate equipment as they rely on primitive and traditional tools due to lack of direct investment which limit the productivity of Sepiolite production.. It is also important to point out that there are no elevator systems or stairs built into the sides allowing people to descend deep into the Sepiolite wells or pits (Figure 4-2). Plastic buckets with long rope attached to the handle or normally *wadaan* made by skin of goats or sheep are usually used to lift up extracted wet Sepiolite clays from bottom of wells.

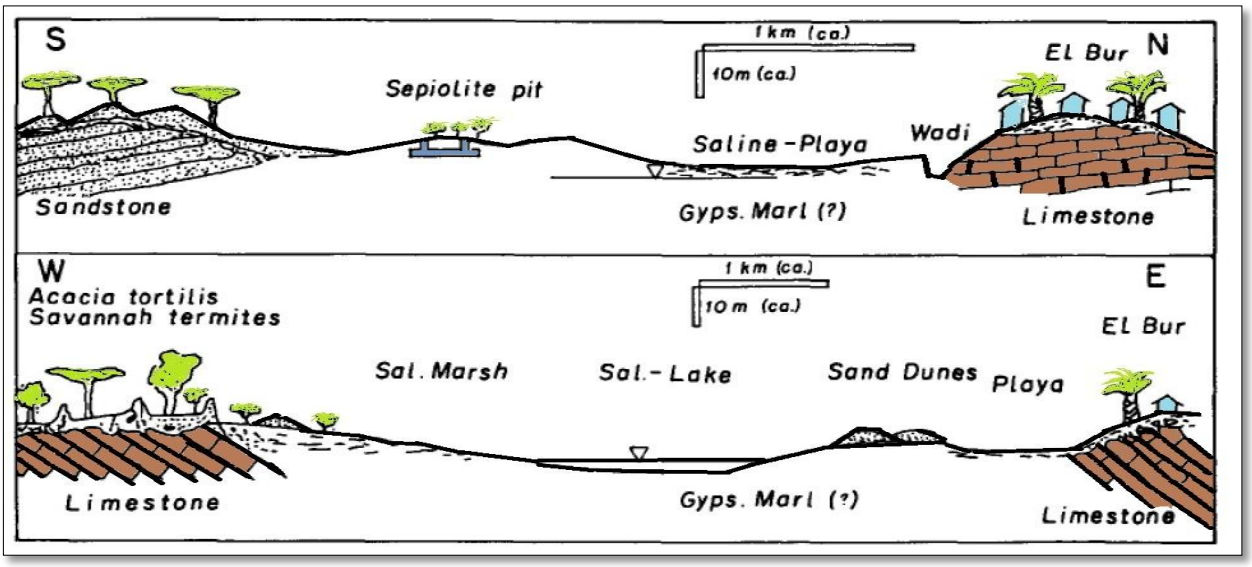


**Figure 4-1 Schematic cross-sections of El-Bur Sepiolite site, seen from North to South (upper) and from East to West (lower) (Singer & Stahr, 1998).**

Sepiolite deposits in El-Bur are sometimes found in levels below the underground waters, which often pose a serious problem for safety of workers as they use very primitive methods. Nevertheless, extracted Sepiolite nodules are initially retained in mines with a humid place by covering with wet sacks to prevent them from losing their structural water and subsequently are dropped them into the water to ensure the soil on them are cleaned. Afterwards, the ones of which soil is taken away are dried and is then loaded in trucks that transport the clay to the processing plant in the city to be further processed and later distributed to markets in Horn of Africa region and to smaller extent to Europe and North America.

**Figure 4-2 Extraction of Sepiolite clay from one the Open-Pits in El-Bur. Photo source (somalimemo.net).**

While it is in the soil, the natural humidity retained by the porous structure of Sepiolite ensures its cleanness and can be easily processed after its extraction (Hande & Mizam, 2011). Sepiolite goes through various phases as indicated in Figure 4-3. Physical properties of good Sepiolite are very white, easily chipped and has no space. Moreover, high-quality Sepiolite gets its original softness when dropped into the water after getting dried and is not subjected to any deformation during wetting and drying and keeps its volume entirely.


**Figure 4-3 Phases of Sepiolite extraction and preparation for usage (Hande & Mizam, 2011).**

## 4.3 Consumption of Sepiolite Clay Mineral in Somalia

Mining of Sepiolite was traditionally practiced in El-Bur over the years extracting Sepiolite clay mineral from the open-pits outside the city producing Burjiko, Dabqaad and art-facts. Burjiko is a charcoal burning stove that is widely used in Somalia and parts in the Horn of Africa region. It has a circular shape, with a deep hole running through its center where charcoal is placed and is used as cooking stove (Figure 4-4a). Dabqaad is also another fire raiser with either one or two handles and is commonly used in Somalia and neighboring countries (Figure 4-4b). Dabqaad has traditionally been used to perfume homes after meals and during special occasions. Frankincense (lubaan) or prepared incense (uunsi), which in the Arabian Peninsula is known as bukhoor, is placed on top of hot Dabqaad and this keeps the house perfumed for hours. With the collapse of former Somali government 1991, substantial numbers of people were migrated into Europe and North of America. As a result, the consumption of Dabqaad has increased among the Somali communities in the western countries.


**Figure 4-4 Wide variety of Sepiolite products {Burjiko (A) and Dabqaad (B)} ready to be transported from El-Bur to the markets of Horn of Africa region.**

Moreover, for over decades, Sepiolite has been used in manufacturing ornament goods as indicated in (Appendix 1). The former Somalia military government built a special building (Sarta Dhagaxleey) in El-Bur city designated to manufacture extracted Sepiolite where local artisans has been using to produce along Burjiko and Dabqaad, Somali art facts resembles Camels, Elephants, Rhino and other Somalia popular wild animals and is brought to the markets for sale.

## 4.4 Industrial applications for Sepiolite

Somalia has large deposits of Sepiolite in El-Bur which is estimated roughly 100 Mt (Chakrabarti, 1988). Only the Indho Qabyo prospect was estimated to have resources of 19 Mt of Sepiolite. On the other hand; an enormous amount of wastes which is about 15-35% of Sepiolite is produced during its preparation due to its soft material. Great part of these wastes is chip which is obtained as a result of peeling of Sepiolite with hand tools such as a knife (Figure 4-5). These chips easily become powder after getting dried. Although is rarely used by local residents, huge chipped Sepiolite waste can be seen in and around Sarta-Dhagexleey which is Sepiolite manufacturing plant in El-Bur designated to manufacture Burjiko, Dabqaad and other artifacts (Appendix 6).

**Figure 4-5 artisans in EL-Bur manufacturing Somali-Style cooker or charcoal burning stove (Burjiko) made from Sepiolite Clay mineral. Photo Source: (somalimemo.net).**

In recent years, the applications and uses of Sepiolite clay have attracted much in the world due to its suitability of structural feature and physiochemical behavior (Galan, 1996). Sepiolite can be used for various industrial applications. For instance, high-quality stones of Sepiolite can be used in manufacturing of decorative natural eco-friendly smoking pipe and ornament goods, whereas waste and low quality stones are utilized as pipe lining and as aggregate in cement at various rates. Furthermore, Sepiolite is used considerably in drilling fluids, where both the viscosity and the gel strength of the mud are not affected by variations in electrolyte content as the case in drilling mud in which bentonite is used (Zhou and Murray, 2003). In Somalia, drilling operations usually experience difficulties particularly in hostile drilling conditions. In this case, Sepiolite drilling mud can be used with salt water particularly when formation brines become a serious problem.

Sepiolite can also be used as pet litters due to its light weight, high liquid absorption and odour control characteristics (Hande & Mizam, 2011). It absorbs pet urine and has a dehydrating effect on solid faeces which minimizes bad smell and inhibits bacteria proliferation. In construction, Sepiolite can be used in lime mortars as water reservoir. The concrete specimens made with Sepiolite wastes are lighter than the specimens made with concrete. The usage of light weight concrete become more popular especially in Belgium, England, Germany, Netherlands, and the USA and its usage rate is still increasing (Hande & Mizam, 2011). However, the outstanding sorptive of Sepiolite provide specific solutions for a wide variety of other industrial applications and are summarized in Table 4-3.

**Table 4-3 Summary of industrial applications of Sepiolite clay mineral (www.ima-europe.eu).**

| No | Industrial applications | Remarks |
|---|---|---|
| 1 | **Industrial absorbents** | Sepiolite absorbs liquid spills and leaks keeping work and transit areas dry and safe. It is a non-flammable material with high liquid absorbing capacity, suitable technical strength of the granules even in wet conditions, and chemical inertness which avoids reaction with absorbed liquids. |
| 2 | **Waste treatment** | Sepiolite absorbs toxic and hazardous wastes in stabilization or inertisation treatments. |
| 3 | **Carrier for chemicals** | Sepiolite absorbs active chemicals, as pesticides, remaining free-flowing and allowing an easy use and effective application of the product in the field. |
| 4 | **Moisture control** | Sepiolite adsorbs excess humidity preventing condensation, corrosion, the proliferation of microorganisms and unpleasant odours. |
| 5 | **Household uses** | Sepiolite has numerous domestic applications such as moisture control, containment of accidental liquid spillages, and use in ashtrays to avoid smoke odour, control of liquid leakages and odours in dustbins, odour removal in refrigerators, etc. |
| 6 | **Animal Feedstuffs** | Sepiolite is registered in the EU as a technological additive for animal feed. Its products are used as binders and anti-caking of free flowing additives as well as excipient of supplements. |
| 7 | **Fertilisers** | Sepiolite improves stability and components suspension of fluid fertilisers in spraying or fertirrigation applications. |
| 8 | **Roof Panels** | Sepiolite improves binding of the components while increasing the fire resistance. |
| 9 | **Bitumens** | Sepiolite allows controlling the rheological properties in heat application systems, improving fire resistance. It also improves the stability and the application in emulsions and asphalt in solvent products. |
| 10 | **Rheological additives for organic systems** | Organically modified Sepiolite allows controlling the rheological behavior of different solvent-based systems as paints, greases, resins and inks enhancing their stability under a wide temperature range and making for easier application |

# 5. Discussion

The results of this study revealed that Sepiolite mining in El-Bur started well before Somalia's independence in 1960. It is mentioned in several reports namely Ahrens (1951) and later Grossher (1978) and Galen (1987) in his review of world reserves of Sepiolite clay mineral. Stahr *et al.* (1990) presented comprehensive description of a Sepiolite occurrence in El-Bur. Moreover, The Federal Statistical Office of Germany (1991) reported a yearly production of 10t of Sepiolite between the years 1985-1987, and 9t in 1982 in El-Bur. Sepiolite mining in this city has however been suffering considerably from a lack of direct investment by both the successive Somali governments and private companies. It is believed that the city hosts large deposits of pure Sepiolite clay mineral reserves. The purity of El Bur Sepiolite supports the argument of Jones & Galen (1988) that the purest Sepiolite deposits are the result of evaporative precipitation from dominantly groundwater-fed shallow water bodies lacking reactive clay detritus. Compared to Eskisehir and Central Anatolian deposits in Turkey are from the Miocene and had formed by the diagenetic replacement of magnesite pebbles with shallow burial under alkaline conditions in the vicinity of paleoshore lines (Ece & Coban, 1994; Yeniyol, 1995). In contrast to these palaeolacustrine environments of formations, the El-Bur Sepiolite is recent or quaternary and appears to be forming at present. As such, this deposit could be likened to the occurrences described by Hay *et al.* (1995) in the Amboseli Basin, East Africa, the Amargosa Desert, Nevada (Hay *et al.,* 1986), and to those described more recently by Webster & Jones (1994) from the southern High Plains, Texas.

In general, however, mining has the potential of contributing considerably to poverty reduction and social and economic empowerment in the country. Weber-Fahr et al (2001) believe that large-scale mining can contribute, through higher incomes, to better nutrition and better education and thus improved health profiles in a community. Martin and Taylor (2012) revealed that, mining has a huge potential to either contribute significantly to poverty reduction and social and economic empowerment. According to Bryn and Hofmann (2007) mineral wealth must be used for broad development purposes that improve the lives of citizens. It is obvious that minerals development generates power for those who share in it and potentially competition for access to it. But, in nations where governance is fragile, this may have a corrosive effect on social and political life and can exacerbate unresolved social tensions, including issues of national versus local authority.

Despite the significant amounts of mineral resources held by El-Bur city and elsewhere in the country, Somalia has so far not reaped the developmental benefits from mineral resources and the country is still one of the poorest countries on earth. But, if properly developed and managed, El-Bur's Sepiolite mineral endowments and other precious minerals in the city such as uranium can play significant role lifting Somalia out of poverty and catapult it to growth and prosperity for the populations. Revenues generated from Sepiolite mining could also contribute significantly Somalia's economic development and achieve greater economic diversification. Therefore, in order to release its mining potential, it is important that Somalia to overcome the obstacles hamper the development of the mining industry in the country. It is evident that the Sepiolite mining industry in El-Bur could

offer unparalleled opportunities for both local and international investors who are seeking expansion to new markets in Somalia. But, this will require deeper reforms and implementation of effective strategies intended at making the mining sector in Somalia in general a key player in economic transformation. Thus, a proactive government action is key essential to the success of Somalia's industrialization strategy. The structural transformation of Somalia economy must be a vital component of any long-term strategy to eradicate poverty and strengthen sustainable growth and development across the country.

On the brighter side, many people believe that Somalia is endowed with enormous natural resources including precious minerals that can be profitably marketed both domestically and internationally but without sustained innovation and human resources development, it would be impossible to overcome the dependence on the initial factor 'endowment'. Thus, it is only strong and capable institutional governance, human development and well-organized economic that makes possible to change the initial factor endowment into a platform to build successful mining industry and diversified economy in Somalia. The Sepiolite mining in El-Bur could be used as an engine for economic growth and as a source of financing to support social sector and poverty reduction in Somalia and revenues generated can be directed to local communities. Harnessing Sepiolite mineral resources in El-Bur for economic development is also vital for improving the quality of life for populations living in this city and would be an important driver for revenue generation, infrastructure development, and poverty reduction though; this will require strategic actions, and a long-term vision.

**Figure 5-1 view from south end of the main bridge of El-Bur during the rainy season. Photo Source: Somalimemo.net.**

On the other hand, land degradation is perceived to be among the greatest environmental problems confronting in the study area. Salinity is the major causes of land degradation in El-Bur due to the presence of Sepiolite in sediments. The presence of Sepiolite in sediments is generally considered diagnasic of highly saline and alkanic environment and as a result, El-Bur is located in areas prone to salinity and is mainly caused by rising groundwater which brings salts to the land surface of the city. The presence of excessive salt content in the soil leads to degradation because the whole composition of soil changes due to excessive presence of salt which is not good for crops to grow.

Evaporative enrichment is also increases salinity levels in surface or groundwater by removing water via evaporation. Levels of salinity in El-Bur usually raise during the Jiaal and Hagaa seasons as higher temperatures increase levels of evaporation. When precipitation increases during Gu and Deyr rainy season, the salinity will decline by diluting the salt water. Meanwhile, the salinity poses threat to infrastructures of the city which has become one of the factors that the city did not expand for the last 30 years. During the Gu rainy season, when water comes into contact with buildings and other infrastructures such as roads, salt is carried with it and as the water evaporates, salt crystals grow and expand which in turn causes physical damage to construction materials and shortens the life of urban infrastructure such as roads and buildings.


**Figure 5-2 map showing the location of Washqo (the Main Salt production site in El-Bur).**

It is also important to note, salt (NaCl) is mined in the Northwest side of El-Bur (Washaqo) which is an area where Salt is an abundant and considered valuable natural resource for the city (Figure 5-2). A salt pan is formed in Washaqo which is water pond located in area where the rate of water evaporation exceeds the rate of water rainfall. Because water in the area is unable to drain into the ground and remains on the surface until it evaporates, leaving behind minerals precipitated from the salt ions dissolved in the water. In gneral, the prevalent land degradation types in El-Bur area are mainly biological degradation and water degradation (Figure 5-3). Reduced soil nutrients by erosion (loss of topsoil by water and wind) reduce crop yields in the city and surrounding areas, whereas the expansion of areas affected by invasive species reduces the land accessible for livestock grazing. In addition, loss of vegetation cover leads to dust storms which pollute the air and affect human health and affect transportation by destroying roads and the main bridges of the city.

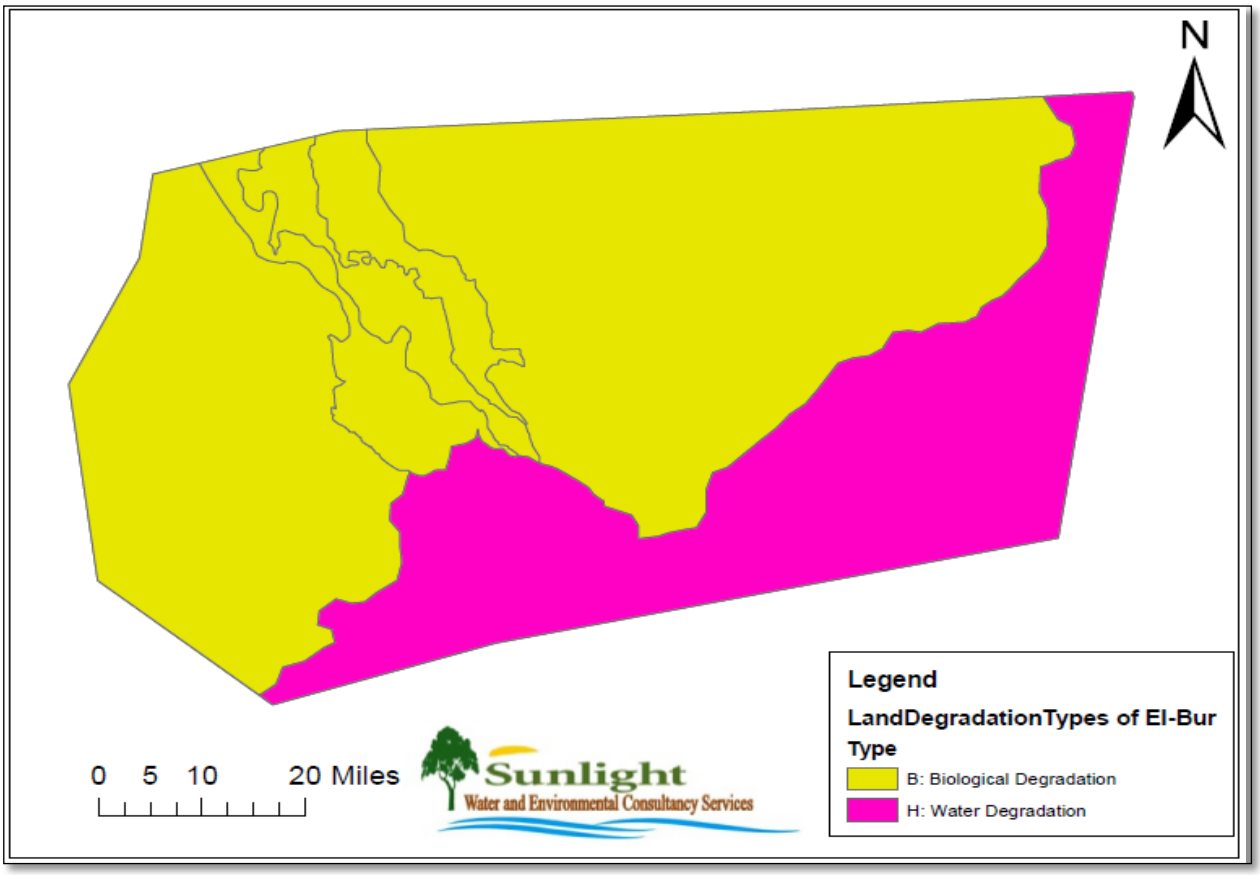


**Figure 5-3 Summary of the major direct causes of land degradation in study area.**

The Normalized Difference Vegetation Index (NDVI) has also been used to observe the scale of vegetation loss in the study area as reduction of vegetation cover and reduced health is identifiable in remotely-sensed multispectral satellite images. Vegetation stress in the study area could be the result of many factors including drought-induced water deficit, insect infestations and failures in precipitation. Figure5-4 shows an example of NDVI map for El-Bur and surrounding areas in January 2003. As the map indicates, NDVI of 1 means the vegetation is healthy which reflects in the NIR region and absorbs the Red part of the electromagnetic radiation. In that case the ratio between

NIR bands would give 1 and the vegetation would look green. On the other hand, NDVI of -1 means that vegetation is unhealthy which also reflects in Red as much as NIR and the ratio becomes zero or less and the vegetation would look yellowish. The highest values of NDVI are found at the South-East of the study area which is an area with a lot of vegetation and forest. It is also a place where there is little urbanization and consequently the NVDI index is not affected by buildings, but the vegetation looks yellowish in North-Western part of the study area including the city of El-Bur.

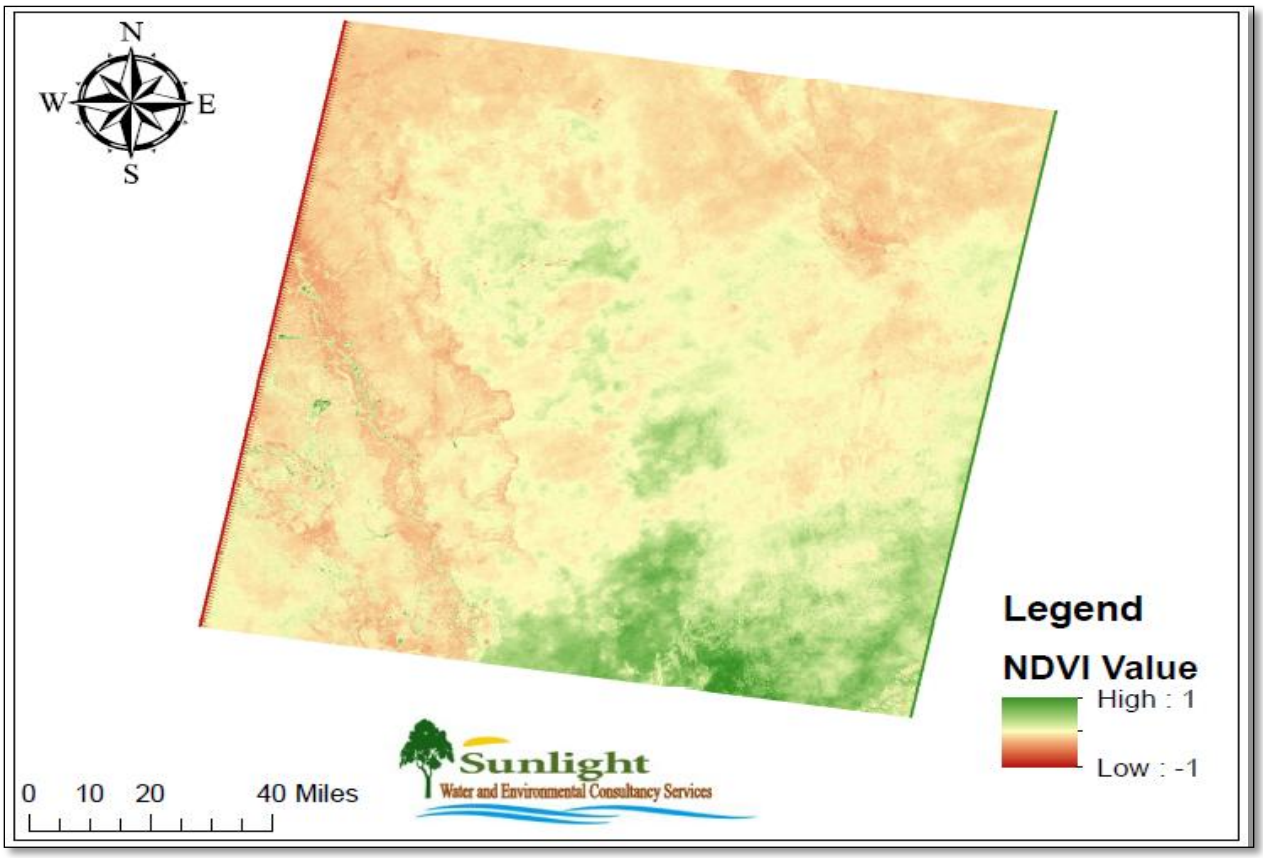


**Figure 5-4 Example NDVI map for El-Bur and surrounding areas.**

It is also interesting to note, apart from the Sepiolite deposits and the unproven reserves of hydrocarbons (oil and gas), the Gal-Mudug province is endowed with uranium deposits (Chakrabarti, 1988). Following numerous mineral explorations in the area between El-Bur, Dusa-mareb, Hobya and South Galkayo was found to contain extensive deposits of uranium in the Taleh Formation that covers Galgaduud and South Mudug Regions (Chakrabarti, 1988). The total uranium metal content of these areas was estimated to be 14.000 tons. Nearly 6.700 ton of the country's uranium resources were estimated to be recoverable at a world market price between $80–130 per Kg. If infrastructure is improved and all-weather roads are built, these resources would be recoverable at a price less than $80 per Kg (World Resources Institute *et al.,* 1996, p. 288). The deposit in Elbur-Ghelinsor area has an estimated resource of 8.000 tons of uranium Oxide (U3O8) from ore that grades 0.116% (Chakrabarti, 1988).

# 6. Conclusions and Recommendations

The study has discussed the properties and industrial applications of El-Bur Sepiolite clay mineral and its potential role in the long-term Somalia's economic development. Sepiolite is surface mined clay mineral that has been traditionally extracted in El-Bur in central Somalia over the years producing charcoal-fired cooking stoves and decorative carvings that are sold to Somali markets and elsewhere in the region. In recent decades, Sepiolite has become on interesting industrial mineral in the world which is served increasing number of usages. It has been used for absorbent purposes for the past hundred years, but it has recently been used to absorb grease, oil, water, chemicals and other undesirable substances spilled on the floor of factories, stations, aircraft hangars. Although, it would be necessary to make profound changes, reforms and implementation of effective strategies intended at making the mining sector in Somalia a key player in economic transformation, it is obvious that the Sepiolite mining industry in El-Bur could offer tremendous opportunities for both local and international investors looking for expansion to new markets in Somalia.

El-Bur has a long history of mining but, so far, the city has not received investment for its clay mineral resources. This is largely due to the absence effective functioning government and lack of integration of Somalia's mining sector into national economic. This status quo is therefore an obstacle to sustainable economic development in Somalia and mining sector in particular. Nevertheless, addressing the challenges facing Somalia's mining industry would significantly improve the outlook of the sector, making it viable and structurally transformative. More importantly, to attract investment into the mining sector in Somalia, the government has to come up with concrete strategies to develop the sector which in turn would encourage mining industrialization, thus boosting the industry's contribution to economic diversification. The markets for Sepiolite have been expanding considerably and will continue to develop in the future due to its special sorptive and catalytic properties which are the basis for many technological applications.

In order to maximize Sepiolite economic benefits for the country and to ensure the greatest possible benefit for the public, it is recommended that comprehensive studies to be initiated for assessing the potential of Sepiolite clay mineral in El-Bur. The Federal Government of Somalia and the Ministry of Petroleum and Mineral Resources in particular are therefore advised, in corporation with the private institutions, to build the capacity of Sepiolite miners in El-Bur and while simultaneously encouraging investment in the sector and develop an appropriate strategy for developing the necessary skills for the miners. The miners are lacking safe and suitable technology and they have been using inappropriate equipment as they rely on traditional tools which reduce Sepiolite production. As a result, the government would consider technical assistance to convert the sector to a sustainable one and address the needs of Sepiolite miners through appropriate channels.

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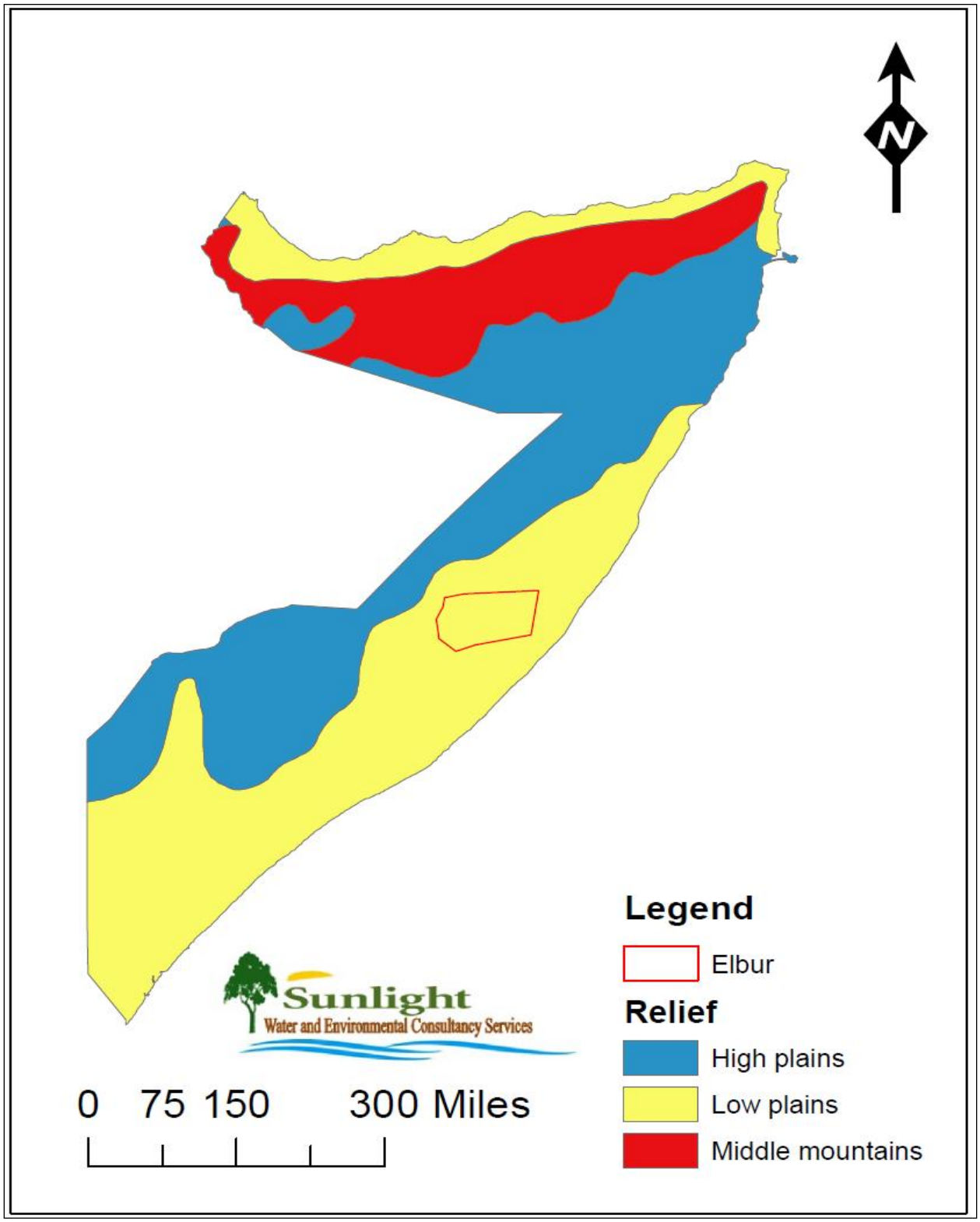
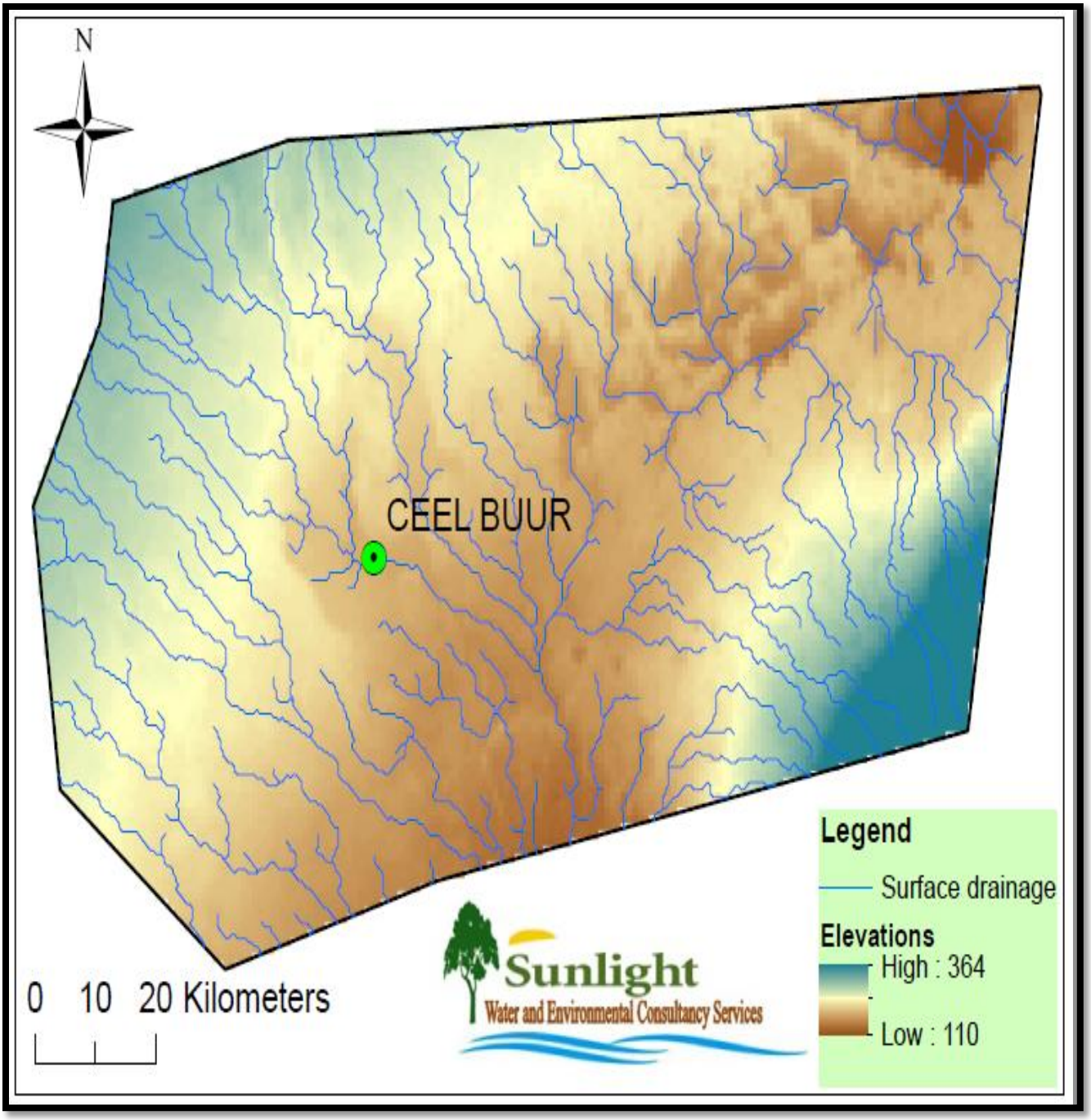
# Appendix 1 Artifacts made from Sepiolite clay mined in El-Bur city

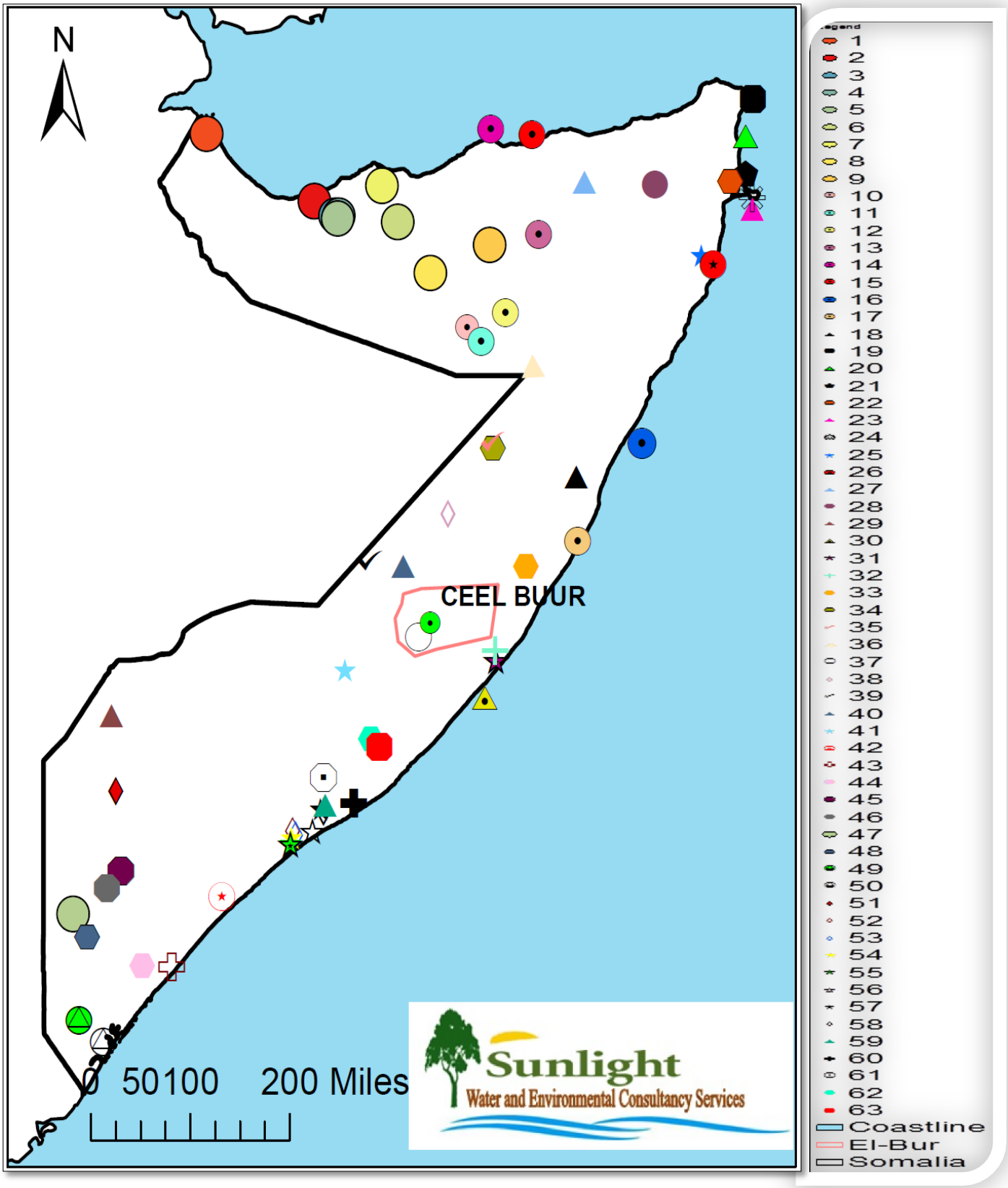
# Appendix 2 Relief Map of Somalia



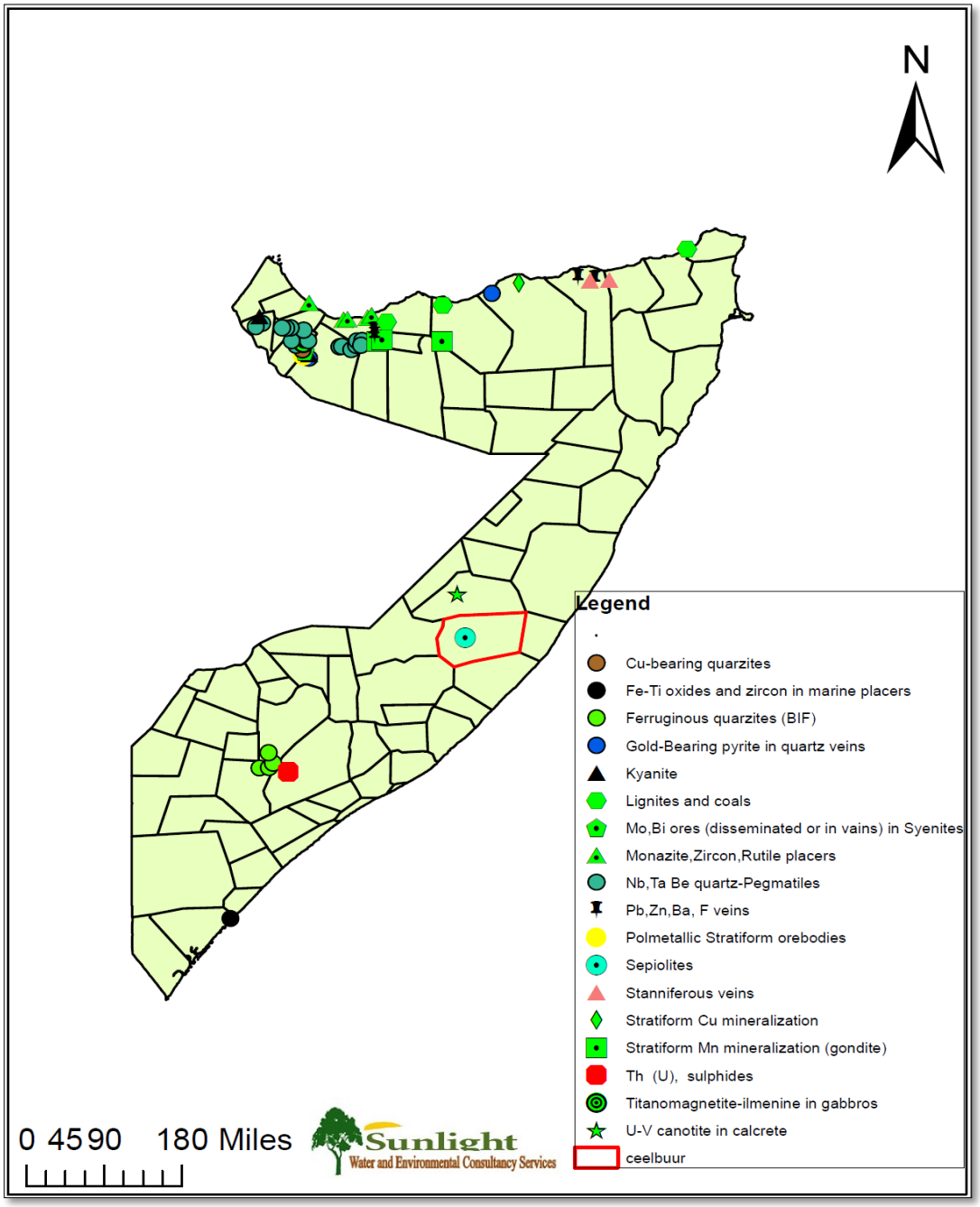
# Appendix 3 Map showing Surface Drainages in the study area



# Appendix 4 Oil Wells in Somalia



# Appendix 5 Distribution of Ore Deposits in Somalia



## Appendix 6 Satellite view of the city of El-Bur