# *GROUNDWATER MODELING OF MIDDLE DARB EL ARBAEIN, SOUTH WESTERN DESERT*

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## ABSTRACT

Darb El Arbaein area was highlighted by agricultural investment. The Nubian Sandstone aquifer is the sole source of water and is Paleozoic- Mesozoic and Upper Cretaceous. The hydrogeological and hydrogeochemical data are collected, gathered, interpreted, and modeled by GIS techniques. The hydraulic conductivity is not suitable for sustainable irrigation (< 3 m/d). The piezometric heads drop within 2000 and 2012 periods was 31-51 m, accompanied with increase in TDS concentration by 148-800 ppm. The average linear velocity of groundwater ranges from $2 * 10^{-7}$ to $1.1 * 10^{-3}$ m/d, while the groundwater volume balance residual for steady state are generally negative values (main area), reflect decline in storage coefficient of the Nubian aquifer (non renewable type to low recharge). Based on hydrogeological parameters overlapping, the best promising area was in the southwestern and northeastern part. The error bar (standard deviation) had highest for the watered area and lowest for Dakhla shale. Multispectral supervised classification of geological map indicate sand sheets (45 %) and Dakhla shale (26 %) represents the highest percentages, while Kurkur (4%) and watered area ( 6 %) are the lowest. Band ratios 7/5, 3/1, and 4/3 reflect high contrast between the main rock units.

**Keywords:** Hydrogeology, hydrogeochemistry, GIS-Remote sensing, Middle Darb El Arbaein

## 1 INTRODUCTION

The General Authority for Rehabilitation Projects and Agricultural Development (GARPAD) create a new community based on an agricultural practices. The groundwater is considered the actual source of water for agricultural and domestic purposes. Therefore, a number of production wells were drilled by GARPAD with an average depth of about 450 m. The annual average precipitation is ≤ 5 mm/year. The mean monthly maximum temperature varies between 13.1 $C^0$ in January and 39.3 $C^0$ in July (Zamzam and Ali 2008). The main objective is the changes in piezomtric heads and TDS concentration of Nubian aquifer within different periods. Here is some questions, is the area suitable for sustainable investment, is there groundwater degradation with time, where is the best promising area to be invest, and real watered area. The last significant question, is the area susceptible to increase the irrigation area.

## 2 GEOLIGY AND HYDROGEOLOGY

The Nubian aquifer is represented by the Paleozoic- Mesozoic sandstone layers and Upper Cretaceous rock units (Taref and Kiseiba Fm.) **(Fig. 1a-b)**. The basement rocks form the base of the aquifer, while the Dakhla Fm. acts as a confining bed of the aquifer. The lithostratigraphic succession is built up of the following rock units from base to top **(Fig. 1a-b)** as following (El Sayed 2005): 1- Pre-Cambrian basement; 2- Paleozoic – Mesozoic sandstones and shale; 3- Upper Cretaceous from top to bottom: Taref Fm. is sandstone with grey shale intercalations; Qusier Fm. claystone alternate with siltstone, sandstone and interaformational conglomerates; and Kiseiba Fm., which is sandstone and ferruginous sandstone with grey shale intercalations. Both of the Taref and Kiseiba Fms. represent the main part of the Nubian Sandstone aquifer system. 4- Tertiary rocks.

## 3 METHODOLOGY

The hydrogeological and hydrogeochemical data are collected within different periods (2000, 2005, 2007, and 2012) from published dissertation. They gathered them and interpret. The data were fed into the GIS model to estimate the different hydrogeological outputs such as best promising area, real watered area, and parameters differences. The illustration were made by GIS techniques. The interpretation were carried out by the author, otherwise noted. The available ETM+ imagery was acquired by Landsat 8, provided in USGS data format. The wavelengths, Quick atmospheric, contrast stretching, radiometric are corrected.

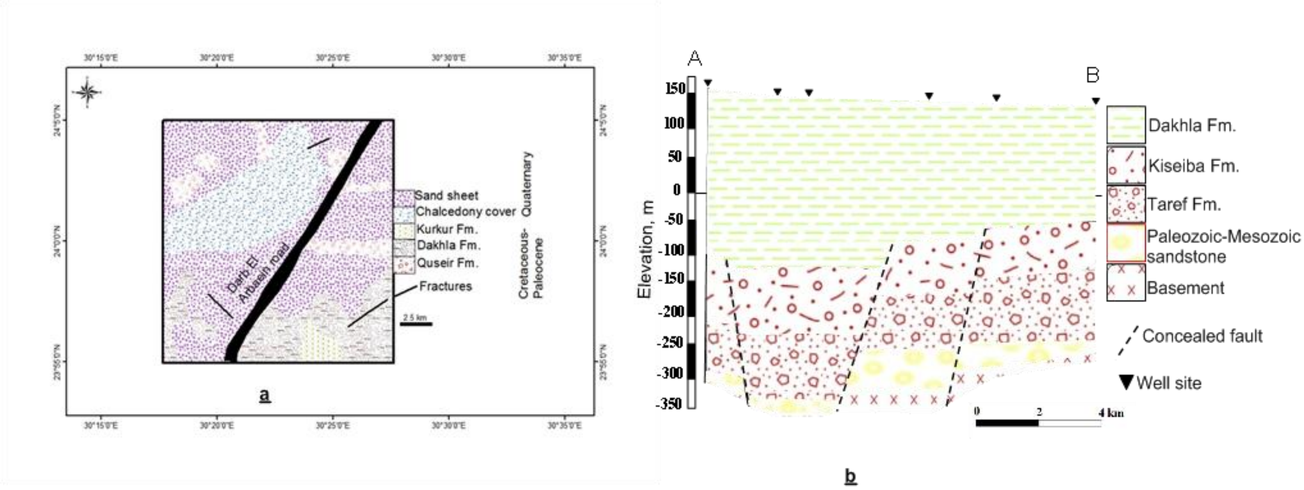


Figure 1. Geology (a) and profile (b) of Middle Darb El Arbaein (modified after Nagaty 2003)

## 4 RESULTS AND DISCUSSION

### 4.1 Hydrogeological parameters

The topography increases from west (160 m) to east (130 m) **(Fig. 2a)**. The saturated thickness ranges from 174 to 241 m with maximum spotted at different sites **(Fig. 2b)**. The lowest basement elevation was due southeastern part, whereas the highest was in the northeastern and southwestern parts **(Fig. 2c)**. The effective porosity increases due the southwestern part **(Fig. 2d)**. The hydraulic conductivity and transmissivity are match; reflect the impact of hydraulic conductivity rather than thickness on the hydrogeological situation. The hydraulic conductivity is generally low (< 3 m/d). It is due to the aquifer is sandstone and ferruginous sandstone with grey shale intercalations (Kiseiba Formation); sandstone with grey shale intercalations (Taref Formation); and very coarse- grained sandstone with grey shale (Paleozoic – Mezozoic).

### 4.2 Historical review of potentiometric levels and TDS concentration

The lowest piezometric head drop was due to highest hydraulic conductivity, transmissivity and more or less highest effective porosity **(Fig. 3a)** in the southwestern part. The maximum drop is characterized by low in hydraulic conductivity and transmissivity. The increase in TDS concentration within 2007 and 2012 periods ranges from ≈ 820 ppm in the southern part to 33 ppm in the northwestern part **(Fig. 3b)**. The TDS concentration differences within 2000 and 2007 periods indicate increase by 32-213 ppm in the central-northeast and southwest **(Fig. 3c)**, while the rest areas decline in TDS concentration. The total increase in TDS concentration within 2000 and 2012 periods ranges from 148 ppm in the north and northwest to 800 ppm due south **(Fig. 3d)**. The pumping rate (180-250 $m^3$/h) from low to very low hydrogeological properties (hydraulic conductivity < 3 m/d), high evaporation, dissolution of geomedia, groundwater flow, all contributed to increase in TDS concentration in groundwater system with time.

### 4.3 Groundwater modeling

The drawdown is generally high, ranges from 50 m due southeast to 20 m in the north and west. It caused by low hydrogeological parameters values resulted from high concentration of fines in aquifer system, high evaporation, and low recharge. The formation and well losses ranges are $2.03 * 10^{-3}$-$6.25 * 10^{-3}$ $d/m^{-2}$ and $1.22 * 10^{-7}$-$4.84 * 10^{-7}$ $d^2/m^{-5}$, respectively (Korany et al 2002).

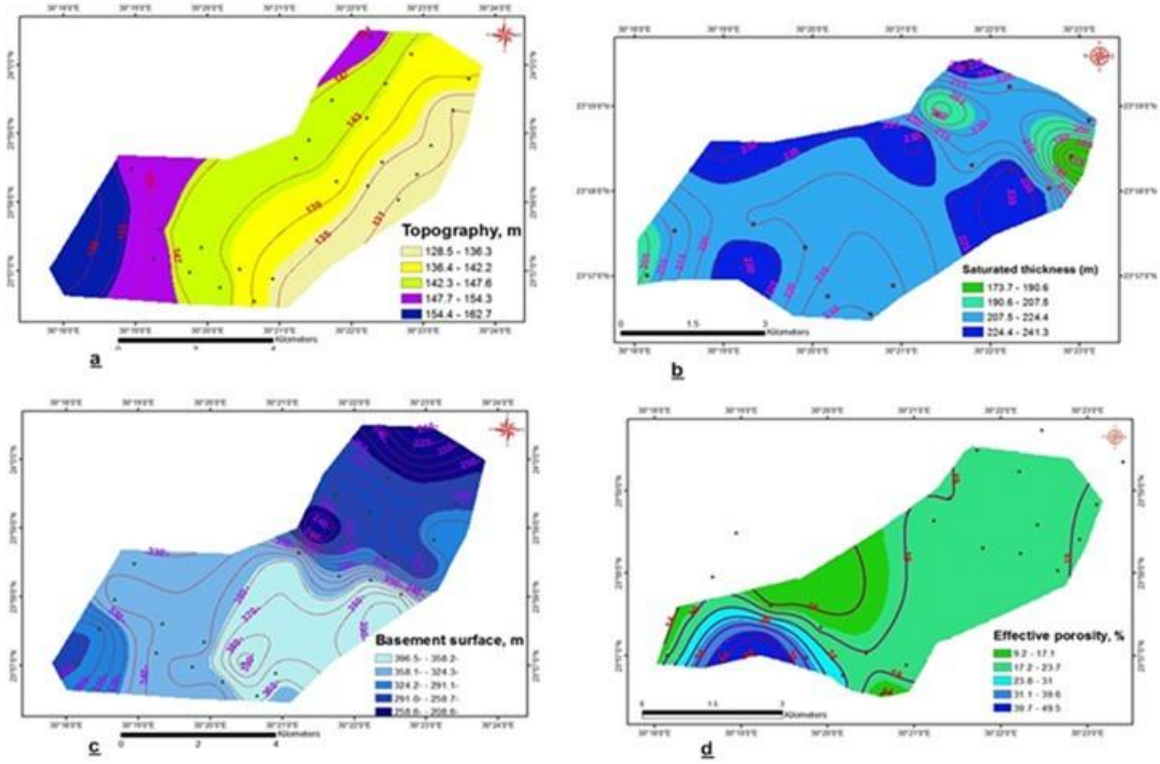


**Figure 2. Geological and hydrogeological parameters**

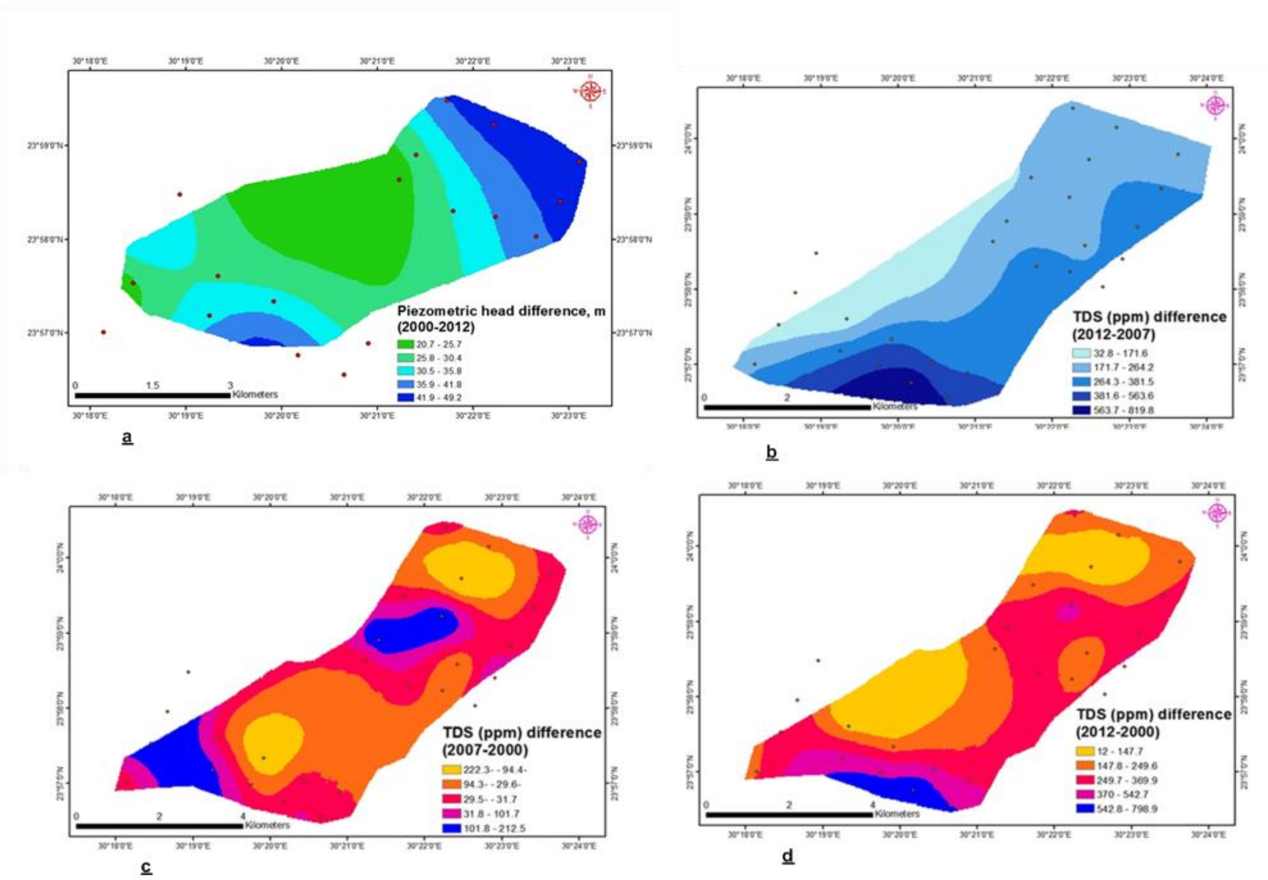


**Figure 3. Piezometric head and TDS concentration differences within different periods**.

The formation loss is much higher than those in well loss, reflect the negative impact of hydrogeological conditions on drawdown besides borehole design and installation. Local steel casing of low resistance to corrosion, short screen length, large ring slot openings and using gravel pack of large size from calcareous materials or without any gravel pack are the main reasons of well failure (Sabri and Shedid 2104). The inputs raster maps into GIS groundwater model are piezometric head, saturated thickness, hydraulic conductivity, and effective porosity. The outputs are average linear velocity and flow vectors **(Fig. 4a-b)**. The highest average linear velocity was due southern part ($8 * 10^{-4} – 1.1 * 10^{-3}$ m/d) and decline to $2 * 10^{-7}$-$2.8 * 10^{-4}$ m/d in the main area. The flow vectors of the groundwater was represented by 360 degrees. If the decision makers ask treatment-recovery-injection techniques for clean up for any contaminant, the best pumped area was in the highest average linear velocity. It enhances the pumping within shorter times with low cost. The groundwater volume balance residual for steady state are generally negative values (main area) ranges from 2 to 90 $m^3$/d, reflect non renewable aquifer type and decline in storage coefficient. The positive values are small patches reach 15 to 85 $m^3$/d. The hydraulic conductivity, drawdown, transmissivity, effective porosity, and saturated thickness are reclassified in GIS model according to potentiality of the aquifer system trend. The best promising area was in the southwestern and northeastern parts **(Fig. 4c)** due to the lowest drawdown and good hydrogeological parameters. The total invested area was 33.2 $km^2$ in Middle Darb El Arbaein, while the real watered area was 0.54 $km^2$/borehole as estimated by GIS model **(Fig. 4d)**. The total watered area was 0.54 * 27 (no. of boreholes) equals 14.6 $km^2$. The previous increase in TDS concentration in groundwater within 2000 and 2012 (12 y) was accompanied with watered area about 14.6 $km^2$.

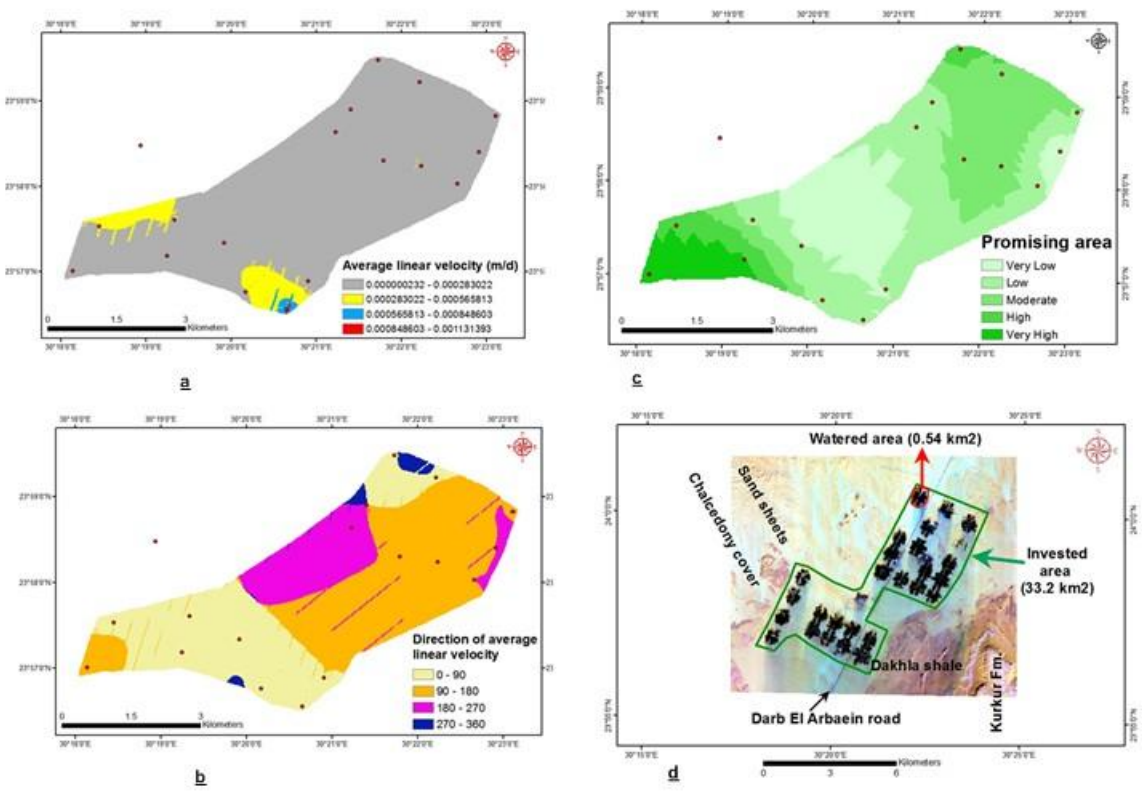


**Figure 4. Drawdown (a), groundwater vetors (b-c), volume (d), promising area (e), and image (f)**

### 4.4 Multispectral Supervised Classification.

Multispectral supervised classification is the process of sorting pixels into a finite number of individual classes or categories of data based on their data file value (Lecia Geosystems, 2003). Therefore, 101 supervised training or areas of interests (AOIs) are selected and controlled to represent 5 categories (rock types) in order to assemble a set of statistics that describe the spectral response pattern of each rock unit. Finally, it can be concluded that multispectral supervised classification is one of the best image processing methods for distinguishing between the main rock units within the study area. The classified geological map **(Fig. 5a)** represents a well base map within the present study that is helpful for further analysis. The map contains 5 classes, which represent the main rock units in the study area. The highest and lowest percentage of the land cover was sand sheets (45 %) and Kurkur Fm. (4 %), respectively. The percentages of chalcedony, Dakhla shale, and watered area (plants) are 26, 19, and 6, respectively.

### 4.5 Compound Band Rationing.

The major target of applying band rationing is to enhance the spectral differences between the image bands and reduce the effects of topography (R.S.I. 2003). Band rationing convey the spectral or color characteristics of the image features regardless of variations in scene illuminations. It is often useful for discriminating spectral variations in a scene that are masked by the brightness variations (Lillesand & Kiefer, 2000). Band rationing is produced by dividing one spectral band by another; producing an image that provides relative band intensities. The hydrothermal band rationing 7/5, 3/1, 4/3 (red, green, blue) **(Fig. 5b)** gives the best output for determining and separating the main rock units in the study area. It is because the Fe-O charge transfer transition is characterized by a broad absorption band at wavelength less than 0.55 $\mu m$ (Badawy 2008). It is responsible for the strong red coloration of rocks rich in iron oxides and hydroxides **(Fig. 5b)**. Occasionally, this coloration is masked by the mixture of iron minerals with large amounts of minerals such as quartz, which is reflected strongly at all wavelengths. The ratio of red to blue reflectance (b3/b1) would enhance the small contribution of iron minerals, giving pixels of iron-bearing rocks a higher value than those composed of pure quartz. Iron also produces an absorption band between 0.85 and 0.92 $\mu m$ owing to crystal-field effects (Badawy 2008). This feature falls within the range of band 4, while high reflectance for all minerals is found in band 5. The ratio of band 5 to band 4; therefore, shows higher values for oxidized iron-rich rocks than for other types. Eventually, the Al-OH and Mg-OH rational effects associated with clays and other hydroxylated minerals result in absorptions within band 7. By rationing this band against band 5, clay-rich rocks manifest dark areas (Drury, 1993). As can be deduced from **Fig. 5b**, several rock formations are recognized according to their tonal and textural characteristics. On the contrary, distinguishing and separation of chalcedony cover and sand sheets rocks depends on data compilation using the available geological maps due to the great similarity of their mineral components that have the same characteristics.

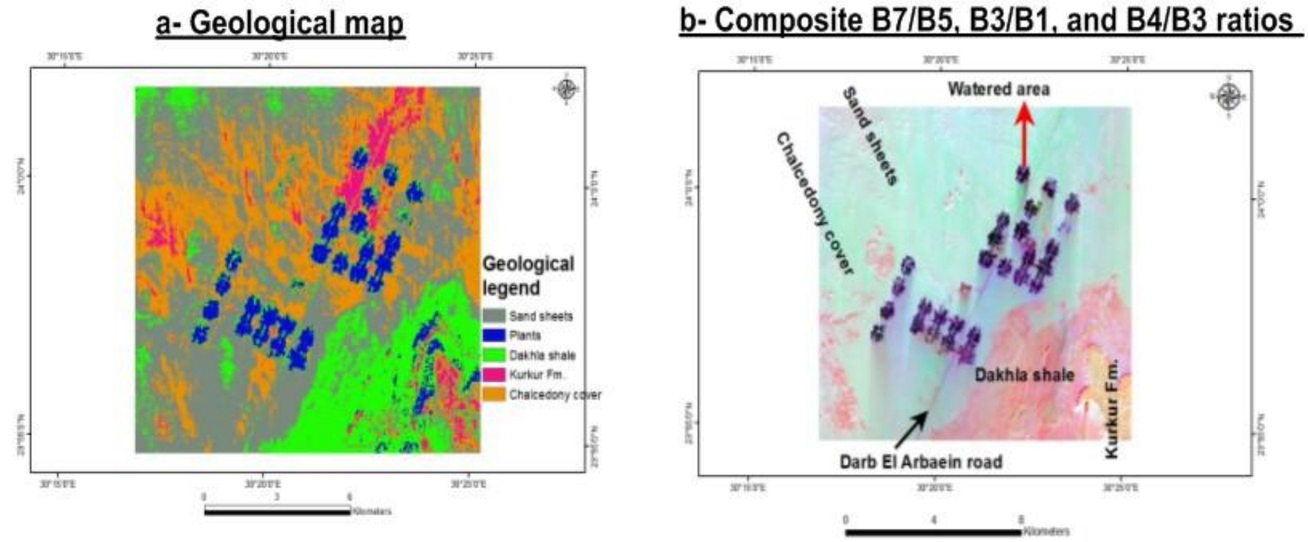


**Figure 5. Selected band ratios of Middle Darb El Arbaein**

## 5 CONCLUSION AND RECOMMENDATION

The drop in piezometric head of Nubian aquifer is maximum (31-50 m) within 2000 and 2012 periods with increase in TDS concentration (148-800 ppm). Bees in mind the real irrigated areas ≈ 15 $km^2$ only. The increase in watered area in the study area should be studied well, otherwise, the TDS concentration degraded due to dissolution of geomedia, low hydrogeological parameters, and unguided borehole design. Band ratios 7/5, 3/1, and 4/3 gives the best output for determining and separating the Land cover.

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