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# Soil monitoring and land cover/land use assessment on the Blue Nile River Watershed, Blue Nile State – Sudan/ using remote sensing and other techniques

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**Abstract:** The study was carried out along the course of the Blue Nile from the Ethiopian-Sudanese border in the south to the borders of the Blue Nile state with Sennar state in the north. The study area was determined by establishing a buffer around the course of the Blue Nile, with a width of 20 km (10 km at each side of the river), Blue Nile state. The study attempted to update some information in the study area regarding land use/ land cover, soil properties and contour map.

To facilitate forest inventory and field work. The study area was divided into equal area to four zones (A, B, C and D), 783 sites and soil sample samples were taken and classified using the land cover classification system (LCCS). The fieldwork and survey began with four practical groups, a group for each zone within the period 1 December 2015 to 5 March, 2016 in a total area of approximately 346483.42 ha.

Remote sensing and fieldwork data analysis showed that there are significant changes in land use/ land cover and soil properties are in the study area (1990 to 2015). Zones A and B (South of Rosieris Dam) are mainly composed of clay soil, while the soil of Zones C and D (North of Rosieris dam) is mainly loamy soil. the study indicate that 13%, 11%, 22% and 19% from zone A, B, C and D respectively lies within the slightly acidity (pH 5.5 to 6.5), while 87%, 87%, 78% and 81% of the same zone respectably was natural soil and 2% of zone B classified as Slightly alkaline soil (pH 8) and more than 50% of the total area classified as neutral to slightly acidity, which is suitable for most crops and natural vegetation covers.

SP% analysis showed that more than 80% of soils samples in the study area have SP% values greater than 40% which characterized combination of silt, loam and clay. The study indicate that the change in the patterns of land cover/ land use systems is found to be mainly due to civil war and economic crises with no clear signs of climatic change.

**Keywords:** Blue Nile River, Land use/ land cover change, Soil monitoring, remote sensing and LCCS.

# مراقبة التربة وتقيم استخدام وغطاء الارض في منطقه تقسيم مياه النيل الازرق – ولاية النيل الازرق – السودان / باستخدام الاستشعار عن بعد وتقنيات أخري

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**المستخلص:** أجريت الدراسة على طول مجرى النيل الأزرق من الحدود الإثيوبية السودانية جنوبا إلى حدود ولاية النيل الأزرق مع ولاية سنار شمالا. تم تحديد منطقة الدراسة من خلال إنشاء منطقة حرم عازل حول مجرى النيل الأزرق بعرض 20 كم (10 كم على كل جانب من جانبي النهر) ، ولاية النيل الأزرق. حاولت الدراسة تحديث بعض المعلومات في منطقة الدراسة فيما يتعلق باستخدام الأراضي، الغطاء الأرضي خصائص التربة والخريطة الكنتورية. لتسهيل الحصر الغابي والعمل الميداني قسمت منطقة الدراسة إلى أربع نطاقات (أ ، ب ، ج ، د) و 783 موقعًا وعينة أخذت من التربة تم تصنيفها باستخدام نظام تصنيف الغطاء الأرضي (LCCS). بدأ المسح بأربع مجموعات عملية، مجموعة لكل منطقة خلال الفترة من 1 ديسمبر 2015 إلى 5 مارس 2016 في مساحة إجمالية تبلغ حوالي 346483.42 هكتار.

اظهر تحليل بيانات الاستشعار عن بعد والعمل الميداني أن هناك تغيرات كبيرة في استخدام الأراضي، الغطاء الأرضي وخصائص التربة داخل منطقة الدراسة وبين نطاقات منطقته الدراسة خلال فترة الدراسة ( 1990 إلى 2015). نطاقات أ ، ب (جنوب سد الرصيرص) بشكل أساسي تتكون من تربة طينية ، في حين أن تربة النطاقين ج ، د (شمال سد الرصيرص) هي في الأساس تربة لوميه (تربه طفليه). تشير الدراسة إلى أن 13٪ ، 11٪ ، 22٪ و 19٪ من النطاقات أ ، ب ، ج ، د على التوالي تقع ضمن درجة حموضة خفيفة (pH 5.5 إلى 6.5) ، بينما 87٪ ، 87٪ ، 78٪ و 81٪ من نفس النطاقات على التتابع عبارة عن تربة متعادلة، 2٪ من النطاق ب صنفت على أنها تربة قليله القلوية (pH 8) بينما أكثر من 50٪ من إجمالي المساحة صنفت على أنها متعادلة إلى خفيفة الحموضة وهي مناسبة لمعظم المحاصيل و الغطاء النباتي الطبيعي. تحليل النسبة المئوية لتشبع التربة بالماء (SP%) اظهر أن أكثر من 80٪ من عينات التربة في منطقة الدراسة لها قيم نسب تشبع بالماء أكبر من 40٪ والتي تميزت باحتوائها علي مزيج من الطمي والطفل والطين. وأشارت الدراسة إلى أن التغيير في أنماط الغطاء الأرضي / أنظمة استخدام الأراضي يرجع بشكل رئيسي إلى الحرب الأهلية والأزمات الاقتصادية.

**الكلمات المفتاحية:** نهر النيل الأزرق، تغير الغطاء الأرضي، مراقبة التربة، الاستشعار عن بعد، نظام تصنيف الغطاء الأرضي.

## 1. Introduction:

Sudan is considered one of the largest Arab countries in the African continent after Algeria with current land area of approximately 1.882.000 $km^2$ (Fig 1) (Sudan, Institute for Security studies, 2011). Its population is approximately 33.4 million (Sudan census report, 2009), 75% of whom live in rural areas. The economy depends predominantly on agriculture, which contributes about 30% of the Gross Domestic Production (GDP) with oil exports gaining momentum. More than Two-thirds of the area of the Sudan is desert, semi-desert or arid. Recurrent droughts have rendered many pastoralists and small-scale cultivators in these areas vulnerable to famine and impoverishment. However, the causes of the present crisis in the rural production systems in the country cannot be attributed to drought and desertification alone. Misguided economic policies have played an important role in the deteriorating situation of the population. Breaking the vicious circle of the ecological stress and the increasing vulnerability of the population of the dry lands requires an increased production from small-scale cultivation and livestock husbandry. Training and research are needed to re-orient development planning in a new direction that considers interaction among local communities, researchers, planners and decision-makers (Ahlcrona., 1985).

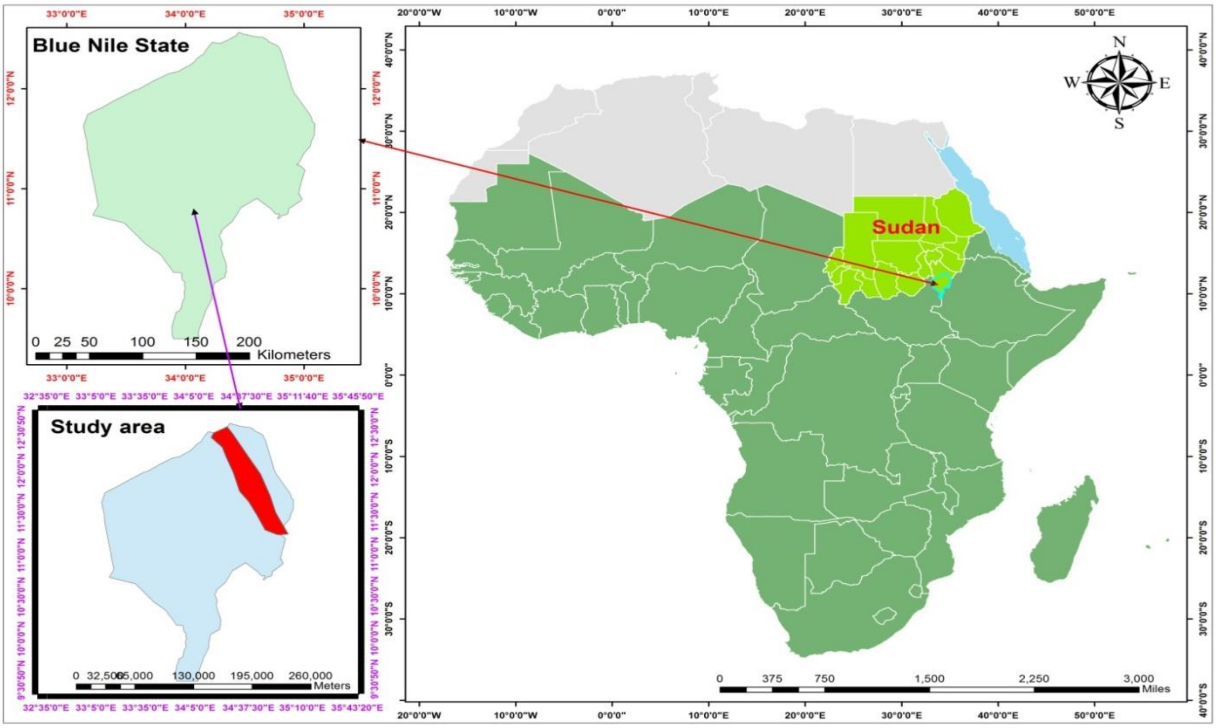


**Fig. 1: The Republic of Sudan**

More recently, the Rosaries and Sinnar reservoirs on the Blue Nile provide the bulk of the water requirements for the Sudan's major irrigated agricultural schemes including the Gezira, Managil and Kenana in the coming future. In fact, two thirds of Sudan's irrigated agriculture lies within Blue Nile Basin. Additionally hydroelectric installation on the Rosaries provides (more than 83% of Sudan installed power capacity). However, there is rapid development of Sudan's agricultural sector through intensification of existing agricultural system (both irrigated and rain fed) and the exploitation of "unused" land (predominantly rain fed). This has led to a number of negative environmental effects on the watersheds, including: the changes in the physical and chemical properties of the soils, Soil physicochemical changes are directly assisted and increased soil erosion, run-off and reduced water retention, pollution of surface & ground water by pesticide derivatives, soil salinization, increased water logging, and increased salt content in the irrigated schemes and large scale expansion resulted in various negative impacts including uncontrolled removal of vegetative cover on the watershed.

The influence of forest on the amount and timing of runoff is of great importance for planning sustainable land use in many regions of the world, not least in the Blue Nile water Catchments area (324,530 km2), the Blue Nile annually contribute 60% of the flow to the Nile River (Conway, 2005: UNESCO, 2004). The annual rainfall ranges 1200-1600 mm/year and the mean annual evapotranspiration 1100 mm/year (Kim et.al. 2007).

The Blue Nile River, which originates from the steep mountains of the Ethiopian Plateau, is the major source of sediment loads in the Nile basin. Soil erosion from the upstream of the basin and the subsequent sedimentation in the downstream area is an immense problem threatening the existing and future water resources development in the Nile basin. The benefits gained by the construction of micro-dams in the Upper Nile are threatened by the rapid loss of storage volume due to excessive sedimentation (El-Swaify and Hurni, 1996; Tamene et al., 2006). Moreover, the green water storage of the Ethiopian highlands, where rain fed agriculture prevails is diminished because of topsoil loss and this has caused frequent agricultural drought (Hurni, 1993; El-Swaify and Hurni, 1996). In the downstream part of the basin (e.g., in Sudan and Egypt) excessive sediment load led to massive operation cost of irrigation canals de-silting, and sediment dredging in front of hydropower turbines. For example, the Sinnar dam has lost 65% of its original storage after 62 years operation (Shahin, 1993) and the other dams (e.g., Rosieres and Khashm el Girba) lost similar proportions since construction (Ahmed, 2004). Both the Nile Basin Initiative and the Ethiopian government are developing ambitious plans of water resources projects in the Upper Blue Nile basin, locally called the Abbay basin (BCEOM, 1999; World Bank, 2006). Thus, an insight into the soil erosion/sedimentation mechanisms and the mitigation measures plays an indispensable role for the sustainable water resources development in the region. Therefore, the study is vital to mitigate the local land cover change which has great impact on local, regional and global scale; also the study finding will help to need of identifying the problem on similar ecosystems

The Sudan government has adopted a national environmental and development policy in 1998 with the aim of achieving sustainable social, economic and environmental development. Among the natural resources, the forest resources occupy a unique position as they provide both goods and services.

Land cover /land use (LCLU) changes play a major role in the study of global change. Negative human activities on natural resources have substantial impact resulted in deforestation, biodiversity loss, global warming and increase of natural disasters.

The assessment and monitoring of extent of LCLU in Sudan is essential for preparing control measures in affected areas that leads ultimately to agricultural development and natural resources sustainability. Thus, the present study was undertaken to achieve the following objectives:

1. To determine and assessments the soil properties in the study area.
2. To determine the land cover and land use types which dominant in the study area.
3. To make recommendations which may assist the agricultural authority for solving the troubles that facing the land cover land use sustainability in the study area.

## 2. Methodology

### 2.1 The Study area

The study area was determined by establishing a buffer around the course of the Blue Nile, with a width of 20 km (10 km at each side of the river), Blue Nile state, Sudan. That represents the direct and effective watershed area of the Blue Nile River in the Blue Nile state (Fig.2). The Blue Nile State is located at the southeastern part of the Sudan in the semi-wet zone. It lies between latitudes 9.30$^{o}$ N and 12.30$^{o}$ N and longitudes 33.5$^{o}$ E and 35.3$^{o}$ E, with a total area of 40000 km$^{2}$ (UNEP, 2010).

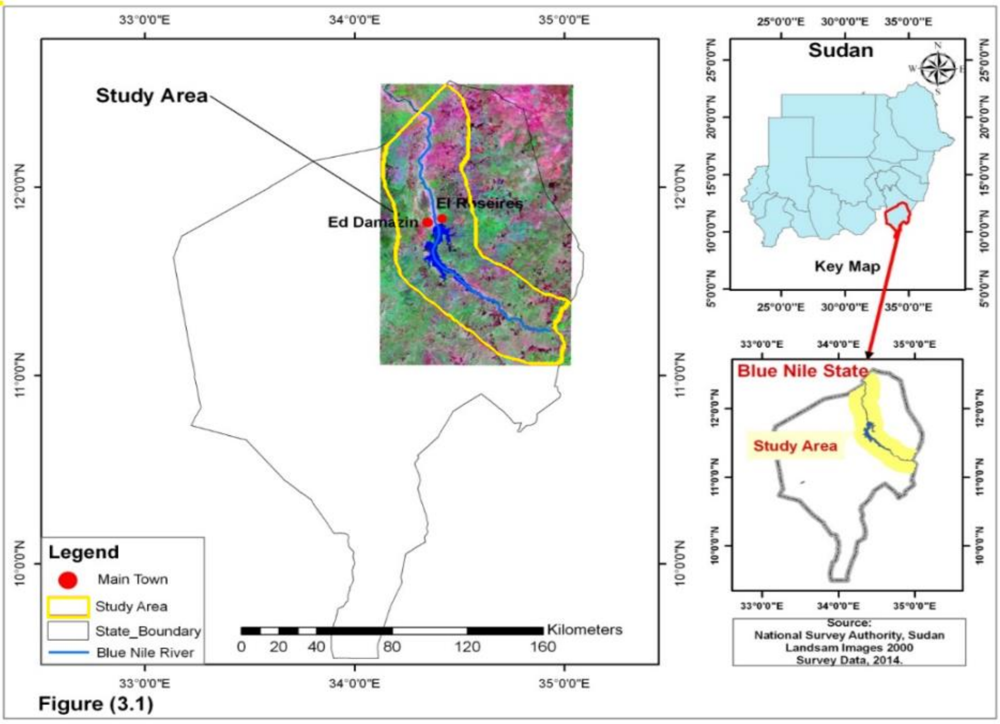


**Figure 2: The Study Area**

Sudan meteorological Authority (Meteorology Office, Damazin, 2017), Classify the region's climate as typical of the high rainfall Woodland Savannah with average of rainfalll between 750 – 1200, it start at May reaches peak at August and ends in October. The relative annual humidity is between 60 – 65% and the average annual temperature range between 35-40$^{o}$ C. ((Meteorology Office, Damazin, 2017). However, In Gessan locality and south locality of Baw and Rosaries the annual rain fall range between 700-900 mm, while the third zone is characterized with an annual rainfall range between 450-700 mm

(Blue Nile investment Map,2004) the average daily temperature range from 31°C in the summer to 22°C in winter (UNEP, 2010).

The State is characterized by the presence of various soil types; the most important being the southern central clay plain. This soil is heavy cracking clay with dark grey or dark brown color. The areas far from the Blue Nile banks are covered with soils known as " Karab". The plateau soils comprise two million feddan, and include the slope of the Ethiopian plateau and hills. These soils are clayey while others are sandy. The surface layers in some of them are acidic and lower layers are alkaline.

## 2.2 Materials:

### 2.2.1 Remote Sensing data

Four subset of land sat images covering the study area and digital elevation model (DEM) were used in this study (Table 1), Images 2010 and 2015 were enhanced Thematic Mapper (ETM), while images 2000 and 1990 were thematic mapper (TM). DEM was used to extracts and cary out contour map and some hydrological information in the study area. The characteristics of these images are shown in Table (1).

**Table 1: Characteristics of imageries used in this study**

| Image | Date | Sensor | Band | Spatial Resolution | Area (km2) |
|---|---|---|---|---|---|
| 1 | Nov /1990 | TM | 1-7 | 30 Meter | 185×185 |
| 2 | Oct /2000 | TM | 1-7 | 30 Meter | 185×185 |
| 3 | Nov/2010 | ETM | 1-7 | 30 Meter | 185×185 |
| 4 | Nov /2015 | OLI/TIRS | 1-8 | 30+15 Meter | 185X185 |

**Path/Row for all the images: 171/52, 172/51 and 172/52 Source: WWW.earthexplorer.USGS.GOV**

### 2.2.2 Fieldwork and Sampling:

Geographic coordinate system (Latitude and longitude) using GPS Garmin 60C was used to site and locate sites samples, sampling map was produced by taking advantage of satellite image interpretations, Sudan land cover 2012 and topographic map. This stage started by entering the coordinates and boundaries of the study area to the GPS. The coordinates then transferred to the appropriate geo-referenced satellite image. A rectangular grid set was used at the spacing of 2 km using fishnet techniques (Figure 3). The study area was divided into Equal area to four zones (A, B, C and D) “Figure 4”, 783 sites and soil sample samples were taken and classified using the land cover classification system (LCCS 1996 and 2012), while the soil samples analyzed using the USDA 2010 guide line. The fieldwork and survey began with four practical groups, a group for each zone within the period 1 December 2015 to 5 March, 2016 in a total area of approximately 346483.43 ha. GPS (Garmin 60C) was used to navigate among check sites, Latitude, longitude and altitude of 783 sites, land use, land cover and soil Sample (0 – 30cm) and other information were collected.

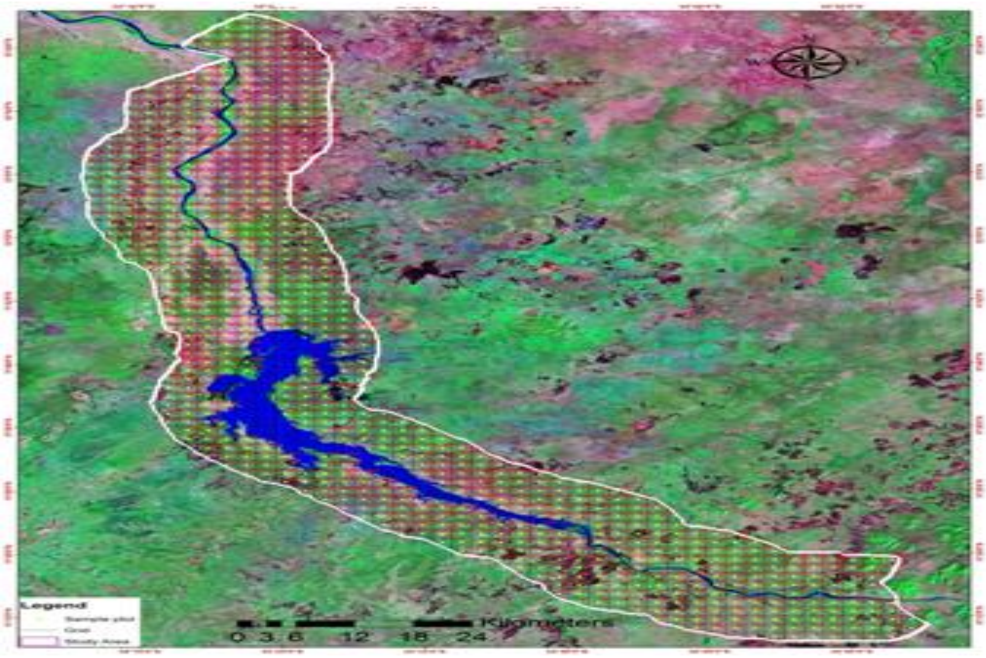


Figure 3: Field samples map

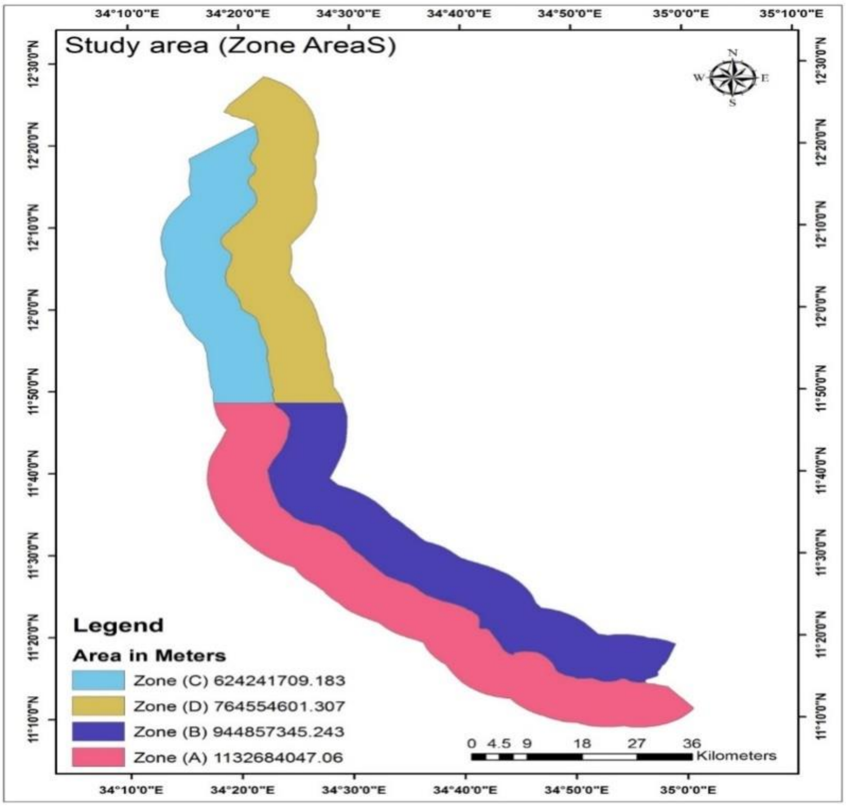


Figure 4: Field samples map

## 2.3 Methods

Land-sat TM and ETM+ images were both used to assess the land degradation and status of land-use changes via map calculation option, during the period extent from 1990 to 2015. Images were acquired in seven and eight bands for Land-sat TM and ETM+ respectively; they covered the visible, near and middle infrared region of the electromagnetic spectrum. Data extraction and segmentation was carried out for partitioning a digital image into multiple segments and also for simplifying and/or change the representation of an image to make them meaningful and easier to analyze.

Soil, land used land cover were examined and classified at 783 sites using the land covers classification system (LCCS 1996 and 2012). Global Positioning System (GPS Garmin 60c) was used to determine the locations of the sample points depending on interpretation of satellite images depends on the morphological and physical soil properties (color, texture, structure...etc.). Soil samples were spread to air dry at room temperature and then grounded using wood pestles and mortars and sieved to pass 2mm sieves. The samples were then kept in well labeled plastic bags for subsequent analysis, to determine the chemical and physical properties according to USDA (2010) that includes: pH of saturated soil paste, Electrical conductivity (EC), Soil texture and Soil Saturation Percentage (SP %).

## 3. Results and Discussion:

Tables (2 to 6) and Figures (5 to 12) present the results obtained for the study area within the period 1990 – 2015.

**Table 2: Soil texture type in the study area (area in hectare)**

| Texture Class | Zone/ area in hectare | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Clay | 211354.9 | 190565.9 | 24253.84 | 27718.67 |
| Clay loam | 6929.668 | 6929.668 | 55437.35 | 34648.34 |
| Loam | 48507.68 | 38113.18 | 194030.7 | 200960.4 |
| Rock | 3464.834 | 0 | 0 | 0 |
| Sand | 0 | 0 | 6929.668 | 6929.668 |
| Sandy clay | 34648.34 | 31183.51 | 45042.84 | 34648.34 |
| Sandy clay loam | 20789.01 | 55437.35 | 0 | 13859.34 |
| Sandy loam | 17324.17 | 24253.84 | 20789.01 | 27718.67 |
| Silty clay loam | 3464.834 | 0 | 0 | 0 |
| Total area | 346483.4 | 346483.4 | 346483.4 | 346483.4 |

Table (2) and figure (7) showed that the area is characterized by wide range of variation in the soil texture although clay soil dominates most of the area. According to Brady (1990), Soil texture refers to the proportion of the soil "separates" that make up the mineral component of soil. Soil texture refers to the primary soil particles (sand, silt, and clay), that formed the mineral component of the soil. According to table (2) and figure (7) Zones A and B (South of Rosieris Dam) are mainly composed of clay soil, while the soil of Zones C and D (North of Rosieris dam) is mainly loamy soil.

Slope Length and Slope gradient (steepness) has been obtained from the DEAM and the sample plot of the study area (Figure 12) showed that the elevation of the study area ranges from 403 to 609 meters above sea level. Low values of the elevation are found on the Zone C and D, southwest central and northeastern part of the study area. High values of the elevation were also obtained in the southeastern corner zone B and southwestern part zone A of the study area. The area south of the Dam has relatively steep slope towards the river bed, while at the northern side the topography is flat so that it is subjected to frequent floods, and hence deposits of loamy soil. Steep slopes normally increase the erosion rate in the absence of dense vegetation cover of trees and grasses. In case of clay soil, surface erosion will lower water purity that travel for longer distances compared to loamy soil as it tends to deposit its particle more quickly due to the presence of sand components. On the other hands, landslides (Haddam) are a characteristic of soil with considerable sand proportion in steep slopes.

**Table 3: Distribution of Soil Reaction (pH) range (area in hectare)**

| pH range | Zone/ area in hectare | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 5.50---6.00 | 17324.17 | 6929.668 | 51972.51 | 38113.18 |
| 6.01---6.50 | 27718.67 | 31183.51 | 24253.84 | 27718.67 |
| 6.59---7.00 | 180171.4 | 187101 | 218284.6 | 221749.4 |
| 7.09---7.50 | 121269.2 | 114339.5 | 51972.51 | 58902.18 |
| 7.59---8.00 | 0 | 6929.668 | 0 | 0 |
| Total area | 346483.4 | 346483.4 | 346483.4 | 346483.4 |

Table (3) and figure (6) showed the soil pH (soil reaction). The pH scale ranges from slightly acidity (5.5) to slightly alkalinity (8), the results indicate that 13%, 11%, 22% and 19% from zone A, B, C and D respectively lies within the slightly acidity (pH 5.5 to 6.5), while 87%, 87%, 78% and 81% of the same zone respectably was natural soil and 2% of zone B classified as Slightly alkaline soil (pH 8), this is also ideal for most crops and natural vegetation.

**Table 4: Distribution of Electrical conductivity range (area in hectare)**

| ECe in ds/m range | Zone/ area in hectare | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 0.01------0.39 | 135128.5 | 190565.9 | 41578.01 | 51972.51 |
| 0.40------0.59 | 65831.85 | 31183.51 | 173241.7 | 190565.9 |
| 0.60------0.79 | 3464.834 | 0 | 13859.34 | 6929.668 |
| 0.80------0.99 | 34648.34 | 17324.17 | 69296.68 | 55437.35 |
| 1.00------2.99 | 107409.9 | 107409.9 | 48507.68 | 41578.01 |
| Total area | 346483.4 | 346483.4 | 346483.4 | 346483.4 |

Table (4) and figure (5) presents Electrical conductivity (EC) for the four zones, 68%, 88%, 86% and 88% from zone A, B, C and d respectively lies within non-saline soil (Ece range 0.01 to 2 ds/m), while 32%, 12%, 14% and 12% from zone A, B, C and D respectively classified as slightly saline soil (Ece range from 2 to 2.99 ds/m). One possibility of such high EC values may attribute to the large lake behind the Rosaries Dam where the opportunities of deposition of silts and concentration of salts leached from the Ethiopian highlands and mountains are very high compared to the areas north of the Dam.

Table 5: Distribution of Percentage Soil saturation (area in hectare)

| SP% range | Zone/ area in hectare | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 20.00-%----39.99% | 31183.508 | 58902.18 | 10394.5 | 17324.17 |
| 40.00%-----59.99% | 55437.347 | 58902.18 | 55437.55 | 65831.85 |
| 60.00%-----79.99% | 218284.75 | 183636.6 | 107409.9 | 76226.75 |
| 80.00%-----99.99% | 41578.21 | 45042.84 | 173241.9 | 187101 |
| Total area | 346483.4 | 346483.4 | 346483.4 | 346483.4 |

As indicated in Table (5) and figure (8) the majority (more than 80%) of soils in the study area have SP values greater than 40% which characterized combination of silt, loam and clay, which confirms the results shown in Table 2. Such type of soil combined with the flat topography of zones B and C (North the Dam) usually ends up with prolong flooding at both sides of the Blue Nile. The only tree species that withstand this condition is found to be Acacia nilotica, and that is why the National Forest Corporation (FNC) of the Sudan reserved considerable areas along the riverbank as plantation forests. The Acacia nilotica plantation forests in this area are found to be quite useful, in addition to their timber economic value, in the control of the river band slide (locally known as hadam).

Table 6: Land cover/Land use trends (years 1990, 2000, 2010 and 2015).

| LCC | 1990 | | 2000 | | 2010 | | 2015 | | +/- |
|---|---|---|---|---|---|---|---|---|---|
| | Area(Ha) | % | Area(Ha) | % | Area(Ha) | % | Area(Ha) | % | |
| Closed Forest | 85768.02 | 24.75 | 8240.78 | 2.37 | 5631.93 | 1.62 | 16965.47 | 4.89 | - |
| Open Forest | 128161.54 | 36.98 | 73201.11 | 21.12 | 48275.6 | 13.93 | 53206.05 | 15.35 | - |
| Agriculture area. | 45341.55 | 13.08 | 166201.02 | 47.96 | 175188.35 | 50.56 | 109378.23 | 31.56 | + |
| Bare Soil | 2967.87 | 0.85 | 7227.84 | 2.08 | 10169.2 | 2.93 | 3252.17 | 0.93 | + |
| Horticulture area | 9784.85 | 2.82 | 16924.57 | 4.88 | 21983.3 | 6.34 | 19026.39 | 5.49 | + |
| Bare Rock | 3750.77 | 1.08 | 3798.97 | 1.09 | 3953.65 | 1.14 | 3757.26 | 1.08 | = |
| Water bodies | 54986.54 | 15.86 | 54086.54 | 15.61 | 54376.7 | 15.69 | 54865.94 | 15.83 | = |
| Urban area | 6042.47 | 1.74 | 6789.98 | 1.95 | 10612.09 | 3.06 | 36802.21 | 10.62 | + |
| Rural area | 9679.81 | 2.79 | 10012.61 | 2.88 | 16292.6 | 4.70 | 7459.90 | 2.15 | = |
| Grass area | 0 | 0 | 0 | 0 | 0 | 0 | 41342.91 | 11.93 | = |
| Island area | 0 | 0 | 0 | 0 | 0 | 0 | 426.87 | 0.12 | = |
| Total area in hectare | 346483.42 | 100 | 346483.42 | 100 | 346483.42 | 100 | 346483.42 | 100 | |

Table (6) and figures (9, 10 and 11) shows negative trends in the total area covered by closed and opened forests and positive trends for those of agriculture, horticulture, Urban area, rural area and bare soil. The closed and open forest witnessed a significant change (deforestation) in 2010 compared to year 2000, 2015 and year 1990, in 1990 the percentage of closed forest is 24.75 while this percentage decreased to 2.37%, 1.62%, and 4.89% in year 2000, 2010 and 2015 respectively. 36.98% Open forest in year 1990 and decreased to 21.12%, 13.93% and 15.35% during year 2000, 2010 and 2015 respectively;

this result could be attributed to the extend the rain-fed agricultural projects, over grazing and cutting trees to produce charcoal and furniture in the study area. Agriculture area, horticulture, urban area and rural area witnessed significant increases in areas during the study period time. No significant change in bare rock, water bodies and island area during this study. The increase in the mechanized agriculture area at the expense of forested areas is expected to have negative environmental consequences. The first immediate effect is the increase of surface erosion rate, which augments the process of siltation in the Dam Lake and decrease the water quality (purity). Other expected immediate effect is the leaching of fertilizers and insecticides from these agricultural schemes and hence increasing water salinity and toxicity, and the decrease of ground water table. At the end, the effect could lead do drought and desertification, which will upset everything in the area. The migration of rural people towards urban area is also another worry as it has the same previous effect of reducing the forested areas around their new settlement areas as they use forest products as energy source and cost-free source of income.

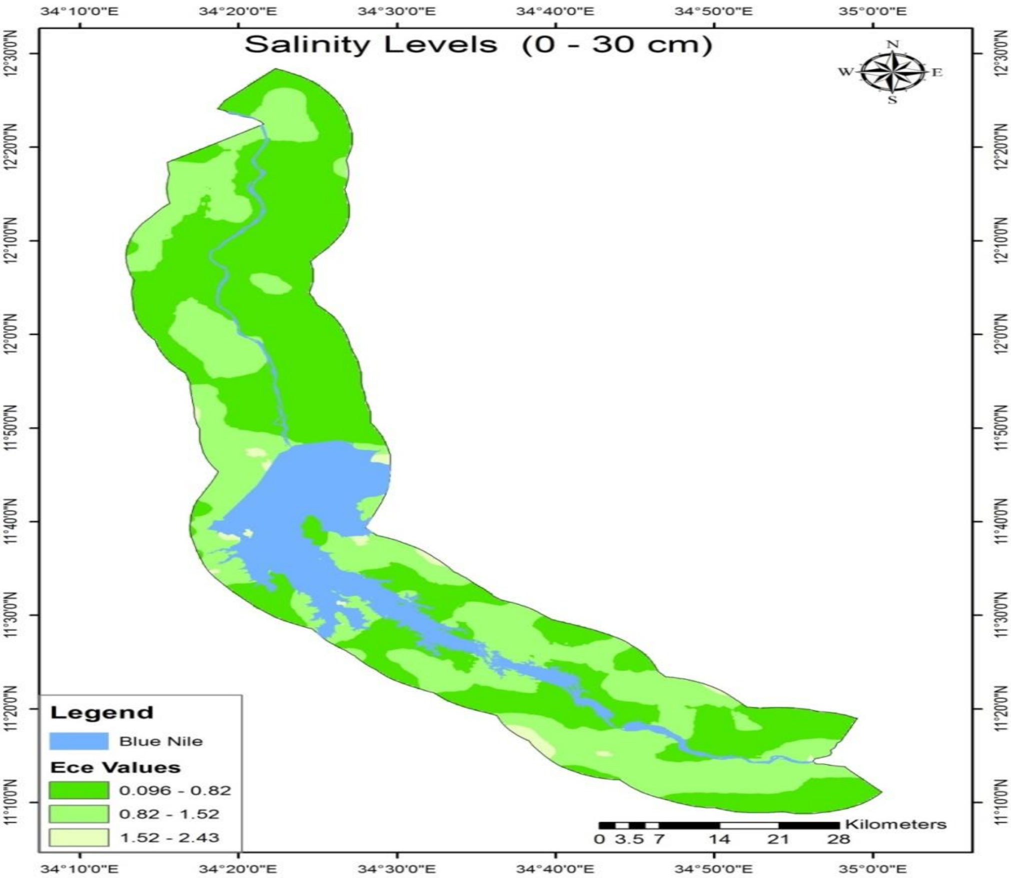


**Figure 5: Study area Salinity levels map.**

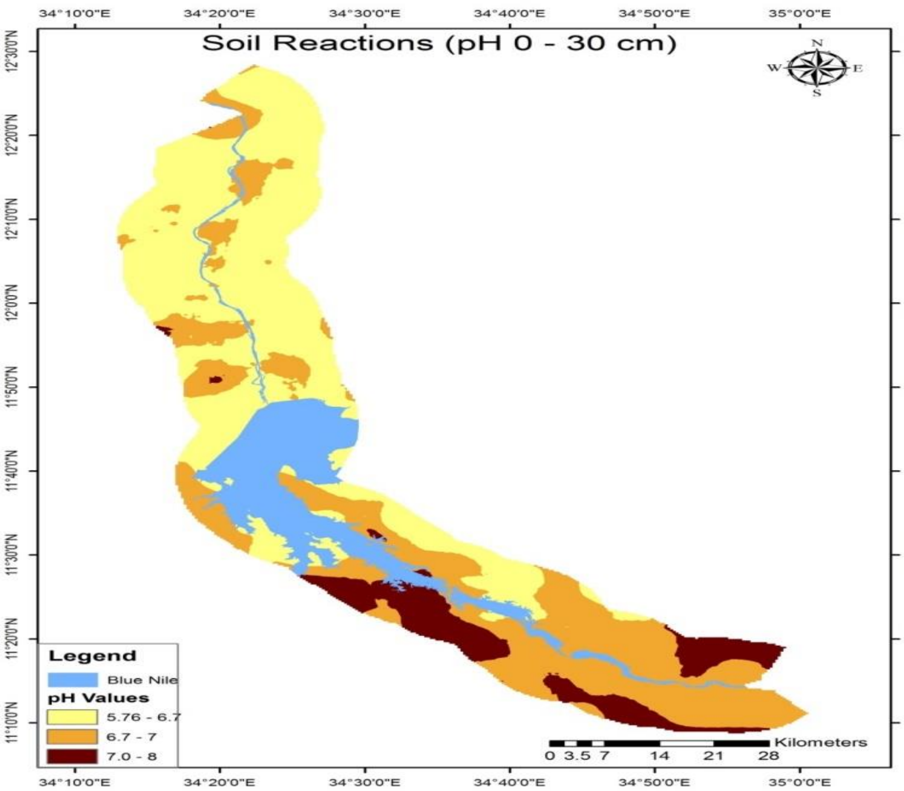


Figure 6: Study area pH levels map.

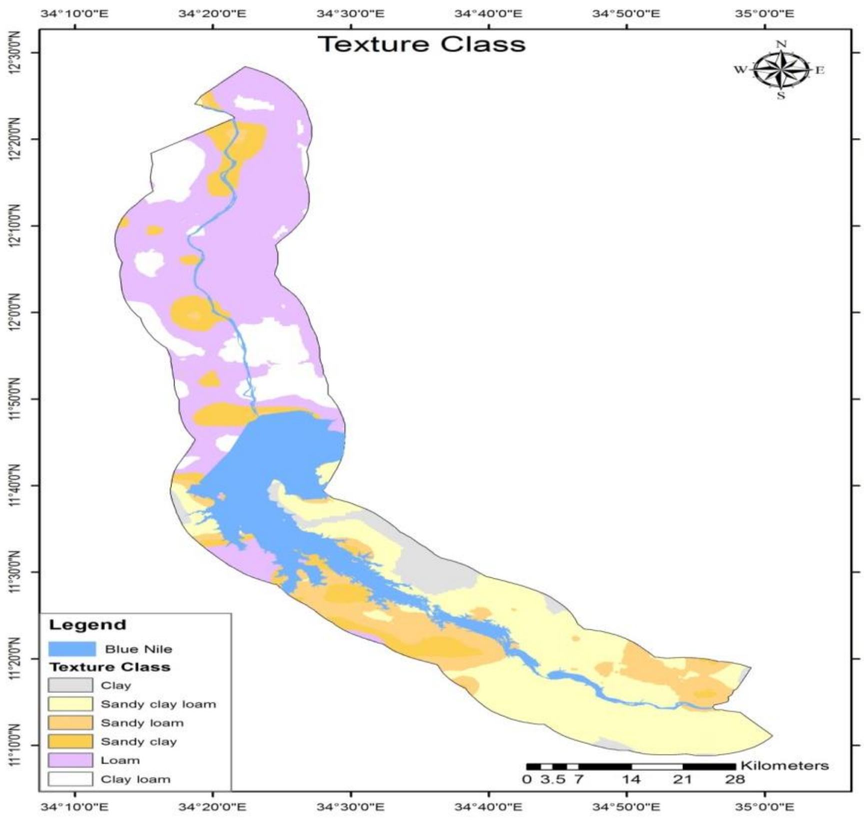


Figure 7: Study area Texture classes map.

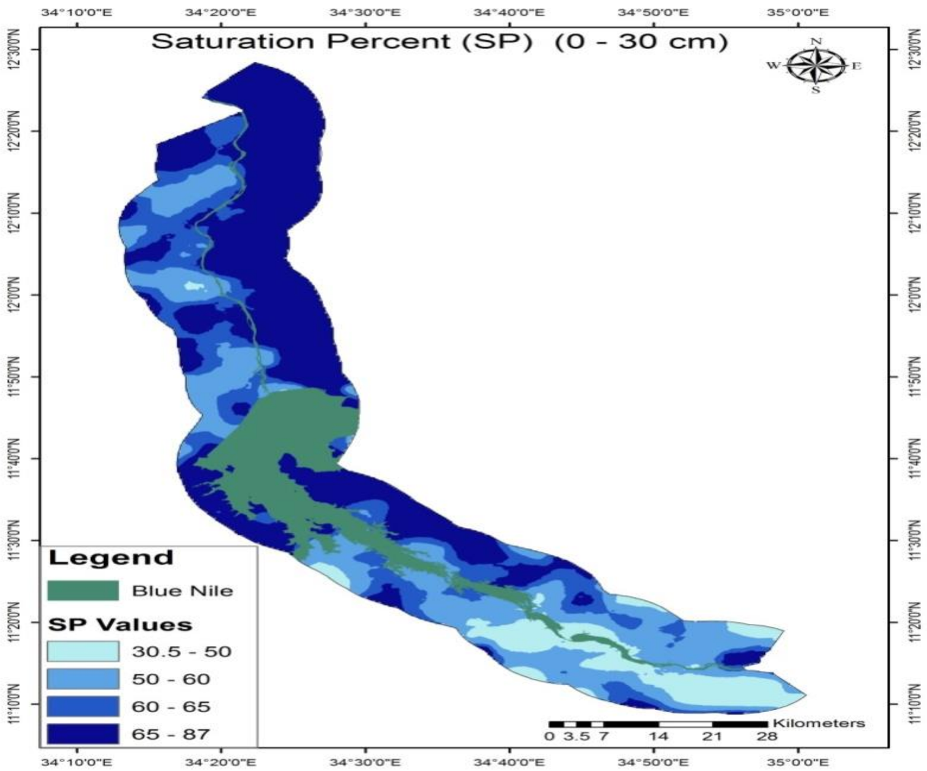


Figure 8: Study area saturation percentage map.

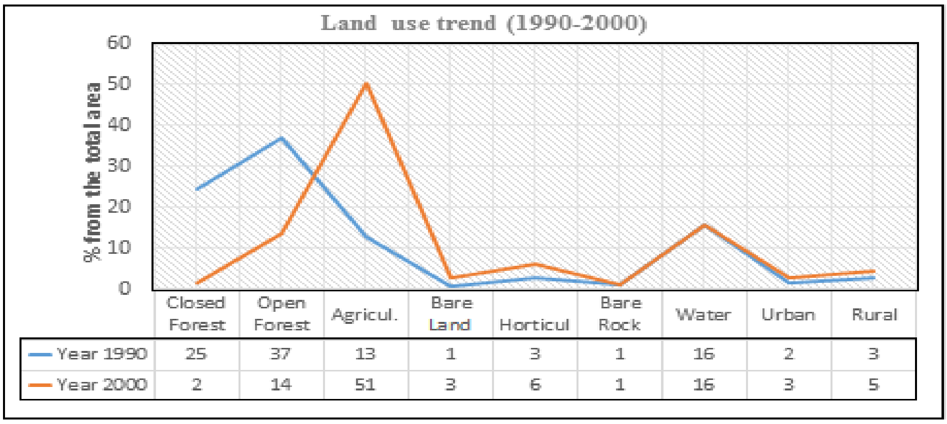


Figure 9: Percentage land cover area change (1990-2000)

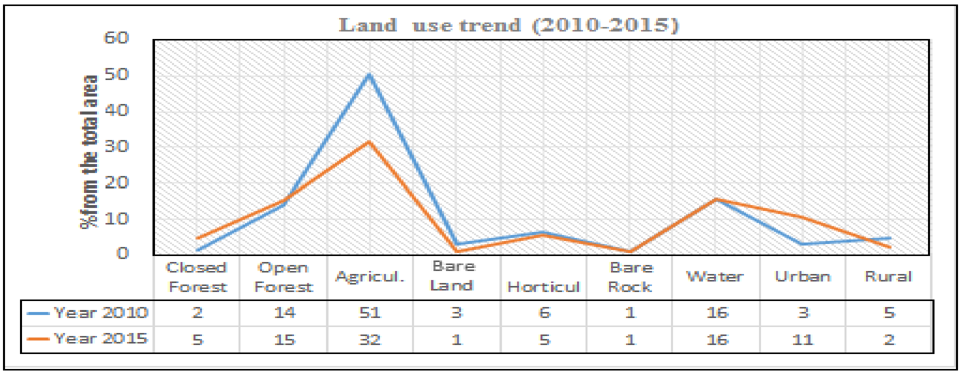


Figure 10: Percentage land cover area change (2010-2015)

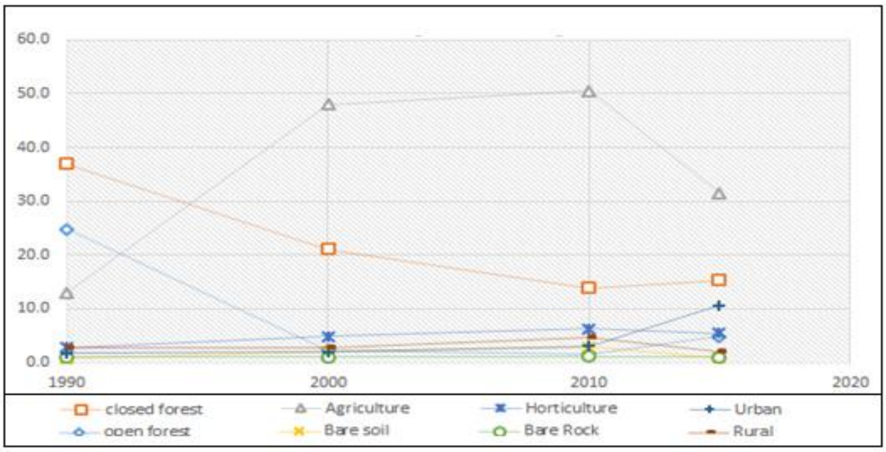


**Figure 11: Percentage land cover area change by years**

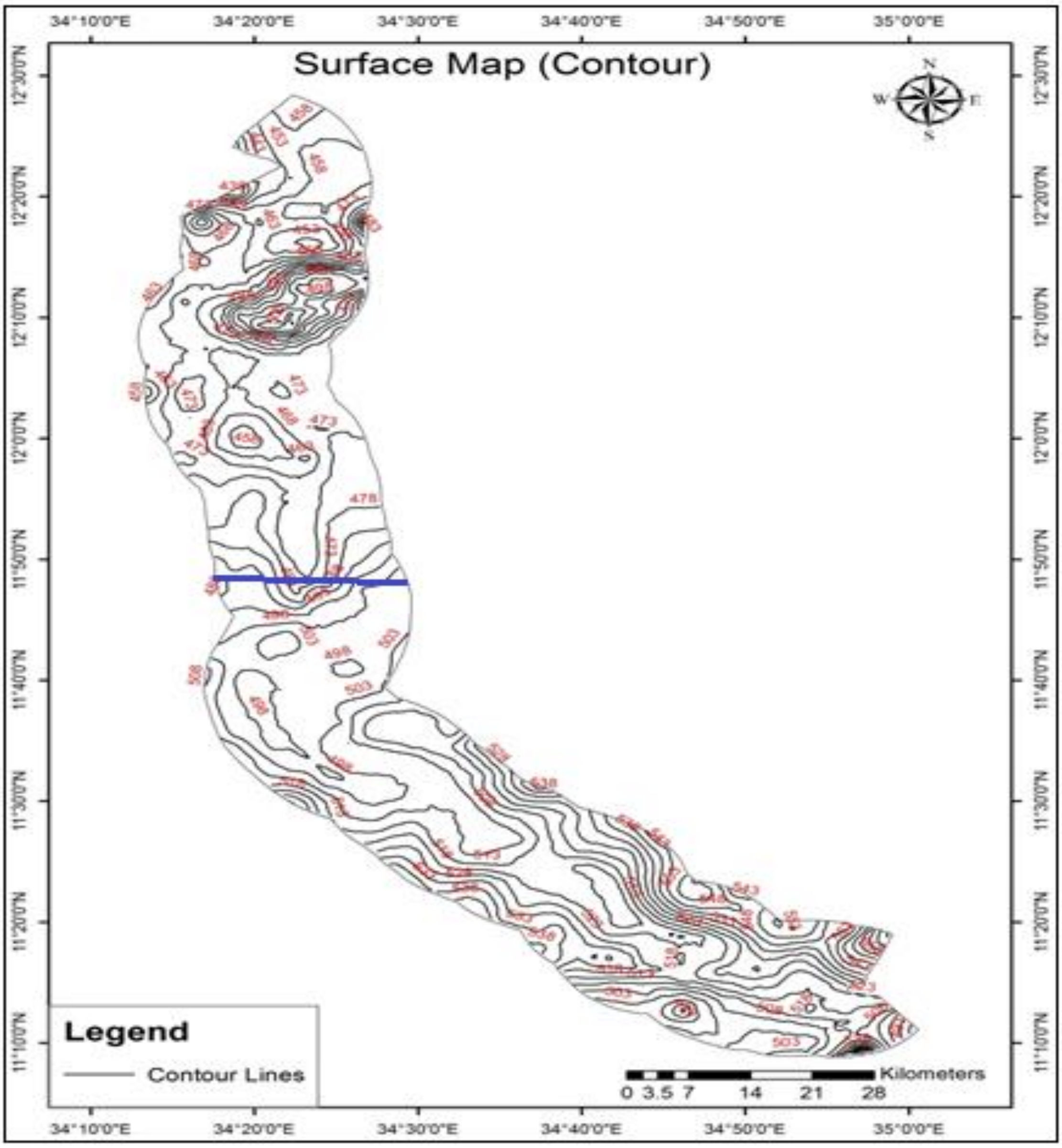


**Figure 12: Surface Map (contour)**

## 4. Conclusion and reommendation

The results showed that land use/ land cover and soil properties in the study area witnessed perceptible change within and between the study period time and this change had negative impact on the environment in general and on the land cover and land use particular as far as quantity and quality of vegetation covers is concerned. The physical and chemical properties of the soil in the area show slightly vary between the study area zones, which has a positive capability of supporting healthy forest and vegetation cover that support proper watershed management.

The change in patterns of land cover/ land use systems is found to be mainly due to civil war and economic crises with no clear signs of climatic change. Expansion in mechanized agriculture, rained agriculture, urbanization and over grazing in the forest land are main causes of the deterioration of the forest cover in the study area and increase of bare land percentage. These changes will have direct negative impact on the soil properties and land cover/use in the Blue Nile area. Designing of appropriate and ideal land use and land cover patterns and in rehabilitate the forest cover are vital in order reducing deforestation in the study area. Rapid changes in land cover and land use with negative human impact activities such as urbanization and conversion of land from use to another should be addressed through taking serious measures which may include:

1- Remote sensing is a powerful technique for monitoring temporal and spatial variation of natural resources and land use/land cover changes Thus, it is recommended to carry out periodically.
2- Raising awareness of the local community to the importance of species diversity and adoption of agro-forestry systems, as well as the continuation of the afforestation and reforestation programs.
3- Adoption of governmental agricultural policy based on the above recommended method of periodical and up-to-date natural resource assessment which can conserve the natural resources.

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