Assessing the Ecological Effect of Petroleum Mining and Operation on Land Cover and Land Use of (Paloch Oil Field Block 3&7) Melut County- Upper Nile State – South Sudan.

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Abstract:
This study was conducted during period between 2015 -2018 in Paloch Oilfield Block 3 & & 7 Melut County in Northern Upper Nile State – South Sudan; the main objective was to study the ecological effect of petroleum mining and operations upon the natural environment, land use systems as well as effect upon the socio-economic systems of local community, also to assess the effect of these activities on the health of human and domestic animals, and biodiversity in the area for the period 2000- 2105. The study used Landsat satellite for the years 2000, 2005, 2010 and 2015 landsat imagery were downloaded, processed and digitally classified using supervised and unsupervised classification .The classification and analysis result showed that, the changes on vegetation cover during first period 2000 - 2005 were significant in its reduction from 41 – 37% of total area, bare land (clay soil) increase from 14 - 20% of total area. The reduction in vegetation and increase in bare land resulted from extensive oil exploration activities within the natural forest where part of them removed for roads, wells, oil produced water ponds and settlement areas, but these effects change it trend during the period between 2010 – 2015 where the changes in percentage is not significant, vegetation cover change from 39 - 40% and sand soil land changed from 12 – 16%   during all period 2000 - 2015. This change was due to reduction in oil exploration activities and reduction of the population in the area during this period because of insecurity resulted from unjust war of 2013 – 2015. Some wild animal's species disturbed and disappeared from the area, except few animals such as rabbits, monkeys which had adapted to the human interventions into the forests. Others animals' species migrate and displaced to safe areas and other neighbor countries. The study recommended that the destructed natural forest and other land use systems should be rehabilitated and restorated by replanting trees, conserving the remain natural forest, organizing the oil production activities through involving the local communities in oil production program in addition to conducting more researches on oil production and mitigating the environmental effect in this area.

Introduction

South Sudan's forests play an important part in the daily lives of South Sudanese people as; 90% of them dependent directly on forests for fuelwood, building material, food and nutrition security, conservation and stability of natural environment through stabilized climate, regulate water cycle, provide habitat of millions of living organisms, produce oxygen, act as carbon sinks which help clean the air of other pollutants and provide excellent barriers against noise pollution, **and** prevent erosion through slowing water runoff, (FAO, 2016)

Petroleum mining is an important land use activity in the forested region, oil exploitation often occurs in the forested areas, construction of oil wells and roads network encouraging deforestation and settlement. *(Global* Forest *Atlas,* 2019).

In 1992 Melut Basin – Blocks 3 & 7 was awarded to Gulf Petroleum Corporation – Sudan (GPC) and in October 1996 GPC was able to drill and reopened Chevron's wells and built an all-weather road from Adar Yale to Melut. Adar Yale was inaugurated in March 1997 with a production capacity of only 5,000 b/d and 10,000 b/d in 1998 respectively. In 2003 the China National Petroleum Corporation (CNPC) announced the discovery of a "world class" oil field in blocks 3 and 7 east of the White Nile, oil production was on average 270,000 b/d and 304, 000 b/d in 2004 respectively

Oil-rich areas in the Melut Basin have suffered the same pattern of oil-related environmental problems, The natural forests have been destroyed; Soil has been degraded and contaminated by petroleum hydrocarbon and adhesive chemicals. Surface water contaminated by produced water and oil spill because most of which has been discharged untreated into the environment. Laurance, 2010 Well drilling affects the environment by the toxic drilling muds which contain radionuclide's which comprise of Uranium, radium, and radon. (Bliss, 2014) The most significant of these impacts on the natural forest and forest land are the access roads, wells and pipeline construction by very heavy equipment's. (Noss and Cooperrider, 1994) In Paloch the oil facilities are too close to the houses, fields and pastures that "not to come close" to these facilities is impossible.(Bliss, 2014) Well, pipe lines and roads where constructed over many villages, Agrisilvo-pastoral land and their natural environment has been severely damaged, and the population has not received substantial benefits. The construction was accompanied by gross human rights abuses, including indiscriminate killing, forced displacement, pillage and arson. (ECOS, 2002).

Study Area

This study are Blocks 3 and 7 mining areas which located in the Melut and Maban Counties,in South Sudan and the coordinate, latitude 10° 44" N, and longitude 32° 20" E (map 1), it has population of 49,242 inhabitants according to 2008 census. The region is one of wide, flat and low lying plains with black cotton soils, covered by Savannah grasslands and acacia trees (Harrison and Jackson, 1958). The area is situated in the semi arid zone with two distinct seasons, rainy season (wet) starts at May to October with annual average precipitation rains between 450 to 550 mm per annum and dry season starts at November to April. The area varies in temperature its main annual is 26.5 ^{0}C, relative humidity percentage is lowest in

April and highest in August. (Department of Meteorology, Renk County 2010. The winds prevail from different directions at different times of the year. The North-East or Northerly and North Westerly trade winds of

moderate velocity prevail during Winter, where as the South and South-East winds prevail during Autumn. Clouds prevail almost eight months in the year, started before the beginning of the rainy season
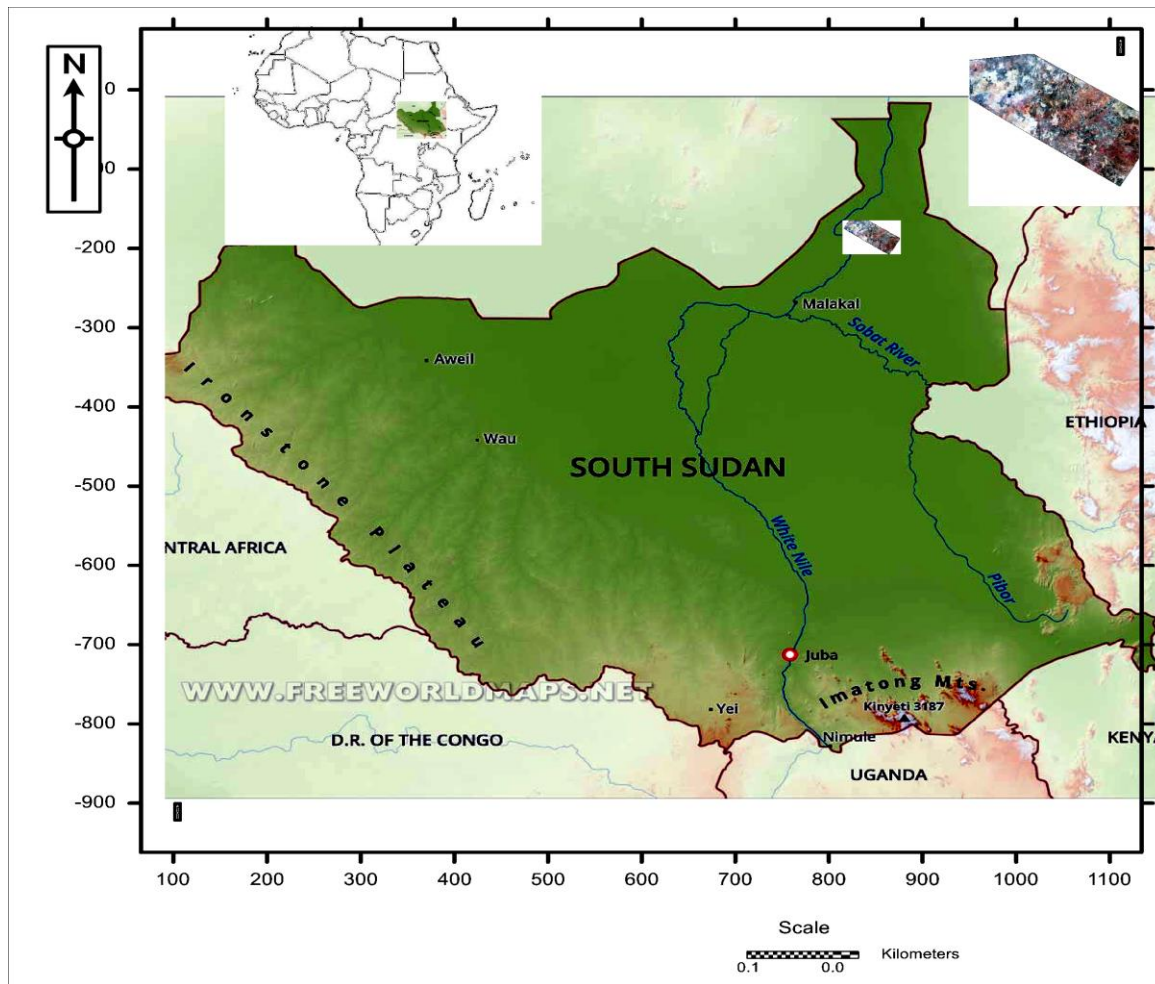
Figure: 1 Map(1): Study Area, Paloch Oilfield (Block 3& 7)

Material and Methods: several type of research materials and methods were used and applied for data collection, data management and data analysis, these are primary data; Google earth image of 2019 digital globe where used for verifying land cover classes. And landset imageries downloaded from United States Geological Survey (USGS)) for year 2000, 2005, 2010 1nd 2015. Software of the Earth Resource

Data Analysis System program (ERDAS 2014) and ENVI 4.7 were used. Global positioning system (GPS) has been used to identify the locations, collecting field observation and Photograph camera for taking photos. Literatures reviews to obtained secondary data from archives, general observations and extensive interviews and questionnaire were conducted and held with 80 respondents

(approximately 0.2% of local population) dealing and affected by petroleum activities. Landsat Path/Row: 172/53: and Path/Row: 173/53: for 2000, 2005, 2010, 2015 imagery was used for change detection by the use of supervised and unsupervised classification procedures (Jensen, 1996).

The site of study area has been divided into four strata according to the effect of petroleum on it, which are land areas affected by oil produced water, land areas affected by oil wells roads and settlement areas, land affected by mining and drilling chemicals and the land which not affected by any activities to be used a s control for comparison of effect in area within the period (before 2000, beginning 2005 middle 2010 and current 2015). These imageries were classified by using two land classification methods;
Supervised Classification and Unsupervised Classification;
Five classes were used via the application to the process of region of interest (ROIs). Maximum likelihood method was chosen as a parametric method. After completing of the classification the results showed that the supervised classification gave good results to distinguish between different areas, after mosaic two imagery there is difficulties to distinguish between the same classes within two map therefore unsupervised classification it become better than supervised one.
The numbers of classes that have been classified were four classes and grouped into land cover classes which include vegetation cover, oil produced water areas, oil wells areas and bare land areas. There are many numbers of classes appeared when classification finished. This makes the differentiation between the classes is extremely difficult and complicated. Performing this classification generated some errors, especially in the vegetation (Mohammed, 2009).

Data Analysis

Description and Variable calculation: The data were analyzed by statistical package of social sciences (SPSS) software, ArcMap. The data analysis were on land vegetation cover, impact of oil roads construction, the impact of wells and pipeline network on land used systems which include natural forest, water resources, agricultural and range land. The results obtained were used for finding extent of degradation, the statistic of normalization data, descriptive data, chart, graphs and simple correlation were drawn using the same statistical software. Also frequency and percentage of variable was calculated. The imagery of 2000, 2005, 2010, and 2015 were processed, managed and classified referring to (McCoy, 2005) method to investigate the changes in land covers, and structures, changes in hydrological patterns and soil composition, changes in human settlements areas, and changes in land use systems and biodiversity areas according to (Singh,1989)

Result and discussion

The result of observation showed that all tree species within and around the roads, oil wells and pipelines net work were observed, scattering of oil wells in all oil field and settlements areas were observed. Therefore, the natural forest land and grazing area were converted into oil wells and roads net work. Large areas of natural forest land, agricultural, and grazing land are converted into oil wells, roads and pipeline net work. Settlement areas are covered and occupied by oil wells and native people were displaced and some of them are still living within and around oil wells, they cultivated cereal crops and grazed their domestic animals around and inside the oil field. The infrastructures are still very poor, no permanent roads net work, no concrete schools and hospital except one in New

Paloch. Oil related diseases such as skin itches, respiratory systems, lungs infection, dryness of all trees species within oil produced were observed, and infections in nervous system where observed and animal mortality were observed.

From interview analysis all native representative interviewed stated that oil production and mining caused negative effect to the area. Most of mass destruction of environment is caused by construction of wells, roads network, cutting and burning charcoal therefore large area of natural forest were cleared off.

From questionnaire analysis showed the condition of natural forest before and after mining and operation, 90% of respondents reported that, the natural forests were vigorous in the area and extremely covered with *Acacia seyal* stand associated with *Balanties aegyptiaca, Acacia senegal and Acacia millifera,* but 8.75% of them said that, the natural forests were moderate and 1.25% said don't know.

Table: 1: Condition of forests before mining and operation of petroleum mining in the study area:

No	Condition	Frequency	Percentage%
1	Vigorous	72	90
2	Moderate	7	8.75
3	Poor	0	0
4	Don't know	1	1.25
Total		80	100

64% of respondent answered that the most destructed land used by petroleum production is cultivated land while 11.25% of them said wildlife habitat and other respectively 7.5% said is natural forest, while 6.25% of them said it is the grazing land.
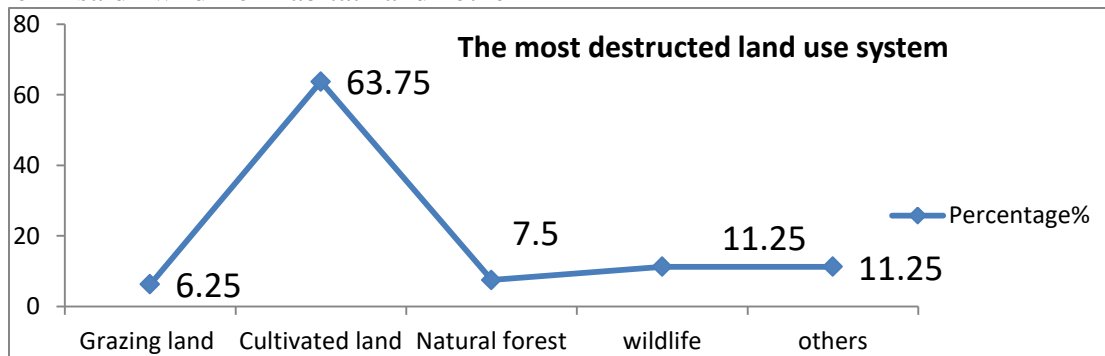
Figure (1) Most destructed land use system by petroleum mining and operation in study area:

Concerning the types of effect on the animals 68.75% answer that there is increase in mortality rate of the animals and 15% of respondents said that the effect is stomach swelling and 8.75% said that effect is eye effect while 6.25% answer that the effect is leg swelling.
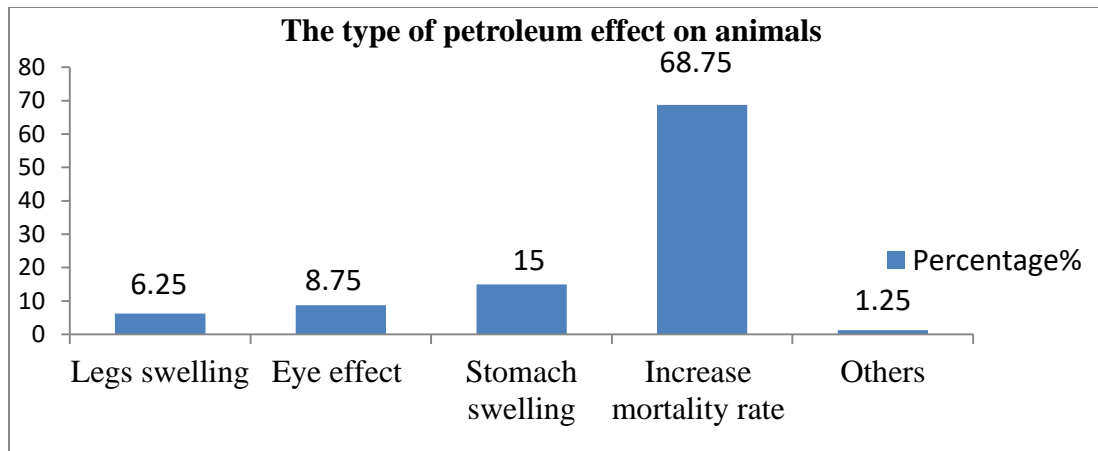
Figure (2) Types of petroleum production effect on the animals.

Concerning the environmental impact assessment conducted before mining activity in oilfield areas 81.25% of respondents answer that there was no environmental impact assessment conducted before mining activity while 18.75% of respondents said that there was environmental impact assessment conducted before mining activity in the area.

Table 2: Environmental Impact Assessment (EIA) conducted before mining activity in oilfield areas

N	E. I. A conducted	Frequency	Percentage
1	Yes	15	18.75
2	No	65	81.25
	Total	80	100

The land covers classification for 2000

The land cover classification for 2000 from satellite 5 TM image (Table3) showed that the majority of field of study was under vegetation cover equal to about 41% (range land 10% Forests land 10% agriculture land 21%), turbidity and oil produced water is 18%, water resources is covering 15%, bare land which include clay soil was equal to about 14% followed by sandy soil which include wells, roads and settlement areas is 12%.
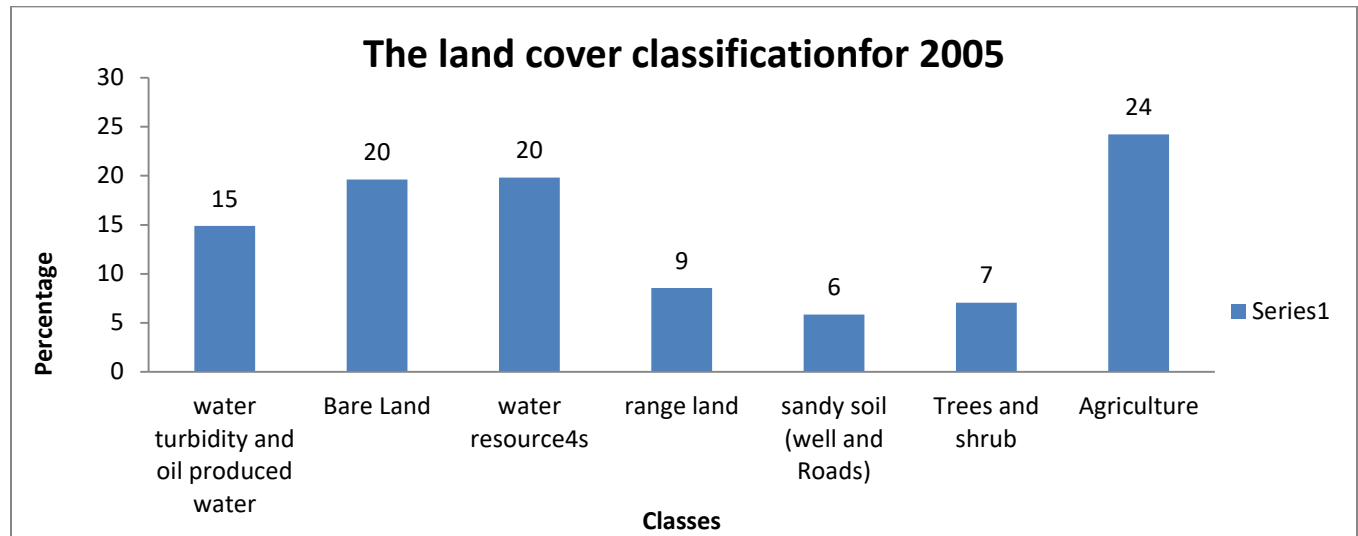
Table (3) the land covers classification for 2000:

No	Land cover classes / year	Area in km^2 2000	percentage
1	Turbidity and oil produced water	718.59	18
2	Bare Land (clay soil)	542.78	14
3	water resources	573.7	15
4	Sandy soil (wells, roads, settlement)	478.51	12
5	Range land	401.29	10
6	Forest land	385.17	10
7	Agricultural land	816.71	21

The land covers classification for 2005

The land cover classification for 2005 from satellite legacy; global survey which is a combination of 5 TM and Landsat 7 Enhanced Thematic image (Fig 3) showed that the majority of study area was under the vegetation cover equal to about 37%% (range land 6%, forest land 7% and agricultural land 24%) followed by two classes in one level bare land 20% and water resources 20% followed by turbidity and oil produced water.

Fig3: Extent and percentages of land cover classes for year2005:

The land covers classification for 2010

The land cover classification for 2010 from satellite 5 TM image showed that the majority of study area was under vegetation cover equal to about 39% followed by water resources accounting for 18% and Sandy Soil (Roads, wells & settlement Areas covering area of 17% and Turbidity, oil produced water and bare land – clay soil are covering 13% respectively.

Table (4) the land covers classification for 2010:

No	Land cover classes / year	Area in km 2010	Percentage
1	Turbidity and oil produced water	526.09	13
2	Bare Land (clay soil)	523.12	13
3	water resources	695.93	18
4	Sandy soil (wells, roads, settlement)	655.34	17
5	Range land	529.97	14
6	Forest	383.52	10
7	Agriculture	602.75	15
	Total	39167	100

The land covers classification for 2015

The land cover classification for 2015 from satellite Landsat 8 Operational Land Imager (OLI) image (Table 5.) showed that the majority of field of study is under vegetation cover equal to about 40% followed by sandy soil which include well, roads and settlement areas and water resources 16% respectively while the water turbidity is equal to about 14% and bare land is 13%.

Table5: Extent and percentages of land cover classes (2015)

No	Land cover classes / year	Area in km 2015	Percentage
1	Turbidity and oil produced water	566.68	14
2	Bare Land (clay soil)	495.76	13
3	water resources	636.95	16
4	Sandy soil (wells, roads, settlement)	638.88	16
5	Range land	579.53	15
6	Forest land	440.36	11
7	Agriculture land	558.34	14
	Total	39167	100

The changes detection for the duration: 2000 - 2005:

Classification maps were generated for the five years and the individual class areas and change statistics for the 5 years are summarized in fig 6 from 2000 to 2005, turbidity and oil Produced water decreased to --135.72km^2 (3%), Bare land – clay soil increased significantly approximately 225.37 km^2 (6%), Water Resources increased 202.84 km^2 (5%),   sandy soil (roads, wells & settlement Areas decreased significantly -143.99 km^2 (3%), bare land increased due to expansion in petroleum mining and operation consequently leading the decrease in land used systems areas because some areas were clear felt and converted to roads, wells, electricity and pipe line net work. Vegetation covers in general decreased (2%) with some changes its percentage after 5 years as follows range land decreased -172.06 km^2 (4%), Forests land decreased -108.63 km^2 (3%) , while Agriculture Land increased 132.56 km^2 (3%).
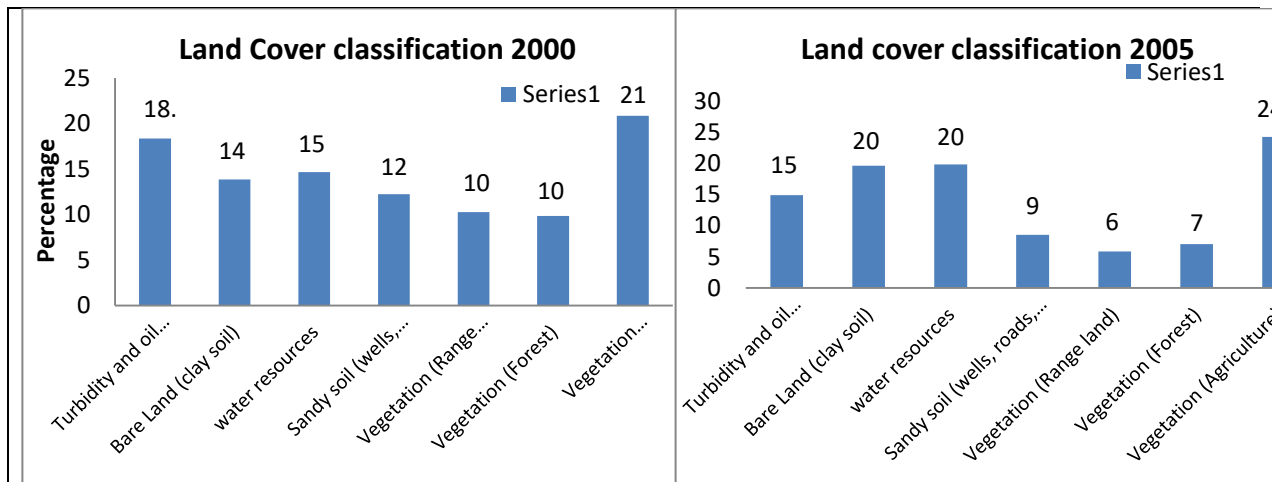
Fig4: Relative changes for 5 years from 2000 - 2005

The changes detection for the duration: 2005 - 2010:

Classification maps were generated for the five years and the individual class areas, and change statistics for the 5 years are summarized in fig5 from 2005 to 2010, turbidity and oil Produced water decreased to -56.78 km^2 (2%), Bare land decreased significantly approximately -245.03 km^2 (7%), Vegetation Cover in general increased 2% with some changes in its classes percentages, Land increased 300.74km^2 (8%), forest land increased 107km^2 (3%)

while , Agriculture Land decreased -346.52 km^2 (9%), , Water Resources decreased -80.61km^2 (2%), Bare which is clay Soil decreased --245.03 km^2 (7%), sandy soil (Roads, wells & settlement areas) increased significantly 320.82 km2 (9%) that is due to expansion in petroleum mining and operation consequently leading the decrease in land used systems areas because some areas were clear felt and converted to roads, wells, electricity and pipe line net work.

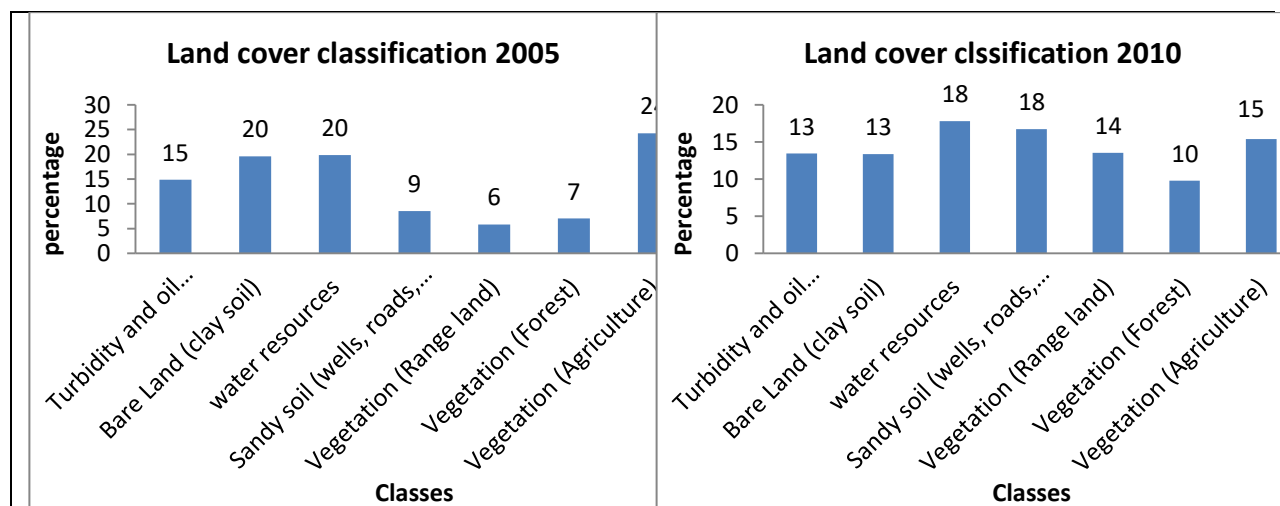Summary of landsat classification and detection change statistics for 2005 – 2010.

Fig5: Relative changes in land cover 2005 – 2010:

The changes detection for the duration: 2010 - 2015:

Classification maps were generated for the five years and the individual class area and change statistics for the 5 years are summarized in table 6 from 2010 to 2015, turbidity & oil produced water increased to $40.59km^2$ (2%), bare land - clay soil decreased approximately $-27.36km^2$ (1%), water resources decrease -58.98 (2%), Sandy Soil (Roads, wells & settlement areas decreased significantly $-16.46km^2$ (1%) that is due to natural regeneration of forest within the areas which were clear felt and destructed by other land used systems. Vegetation cover in general increased 1%, with some changes in it percentages, range land increased $49.56km^2$ (1%), forest land increased $56.84km^2$ (1%) the significant increased in vegetation cover (tree) is resulted from increased of natural regeneration of forest due to reduction of population pressure, reduction of over cutting, reduction in fire frequencies, Agriculture Land increased $-44.41km^2$ (1%),
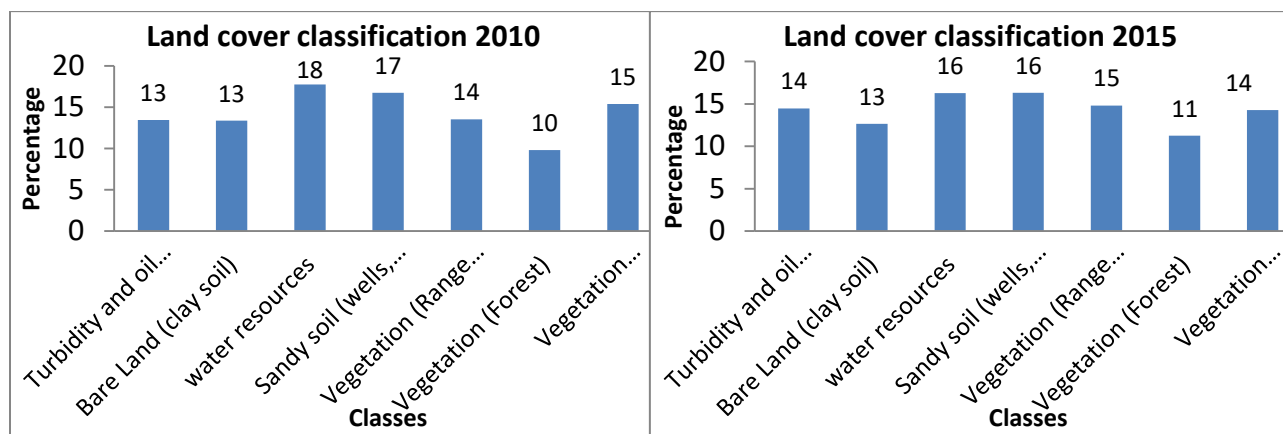
Fig6: Relative changes in land cover 20010 - 2015:

The changes detection in the full period 2000 - 2015:

Classification maps were generated for the fifteen years (Fig7) and the individual class area and change statistics for the 15 years are summarized in Table7 From 2000 to 2015, turbidity and oil Produced water decreased to $-151.91km^2$ (3%), Bare land-clay soil decreased significantly approximately $- 47.02km^2$ (1%), water resources increased 63.25 (1%), Sandy Soil (Roads, wells & settlement Areas increased significantly $160.37km^2$ (4%) that is due to expansion in petroleum mining and operation consequently leading the decrease in land used systems areas because some areas were clear felt and converted to roads, wells, electricity and pipe line net work.

Vegetation cover - range Land decreased $178.24km^2$ (5%), Vegetation Cover (trees) increased $55.19km^2$ (1%) the significant increased in vegetation cover (tree) is resulted from increased of natural regeneration of forest due to reduction of population pressure, reduction of over cutting, reduction in fire frequencies and agriculture Land decreased $-258.37km^2$ (7%),

It is remarkable that an area covered by vegetation was in continuous decrease during all periods while an area covered by sandy soil which include roads, oil well, settlement, electricity and pipeline net work are in continuous increase.
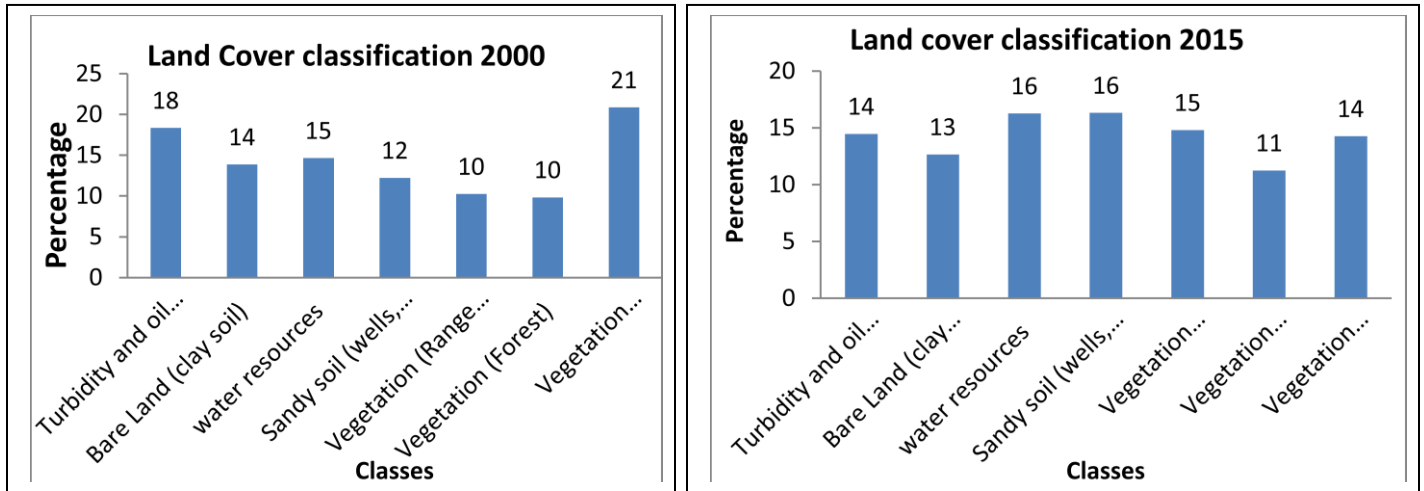
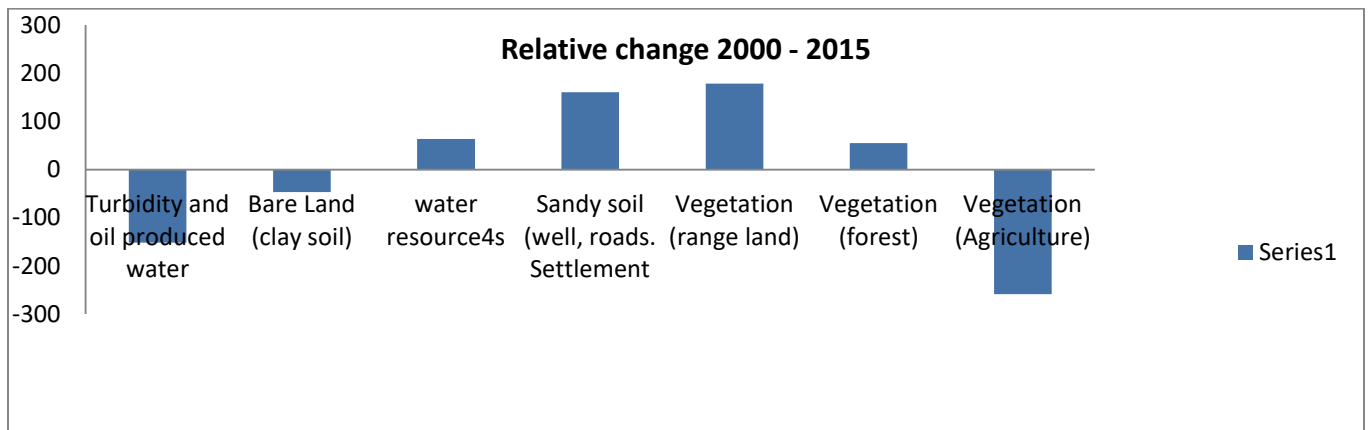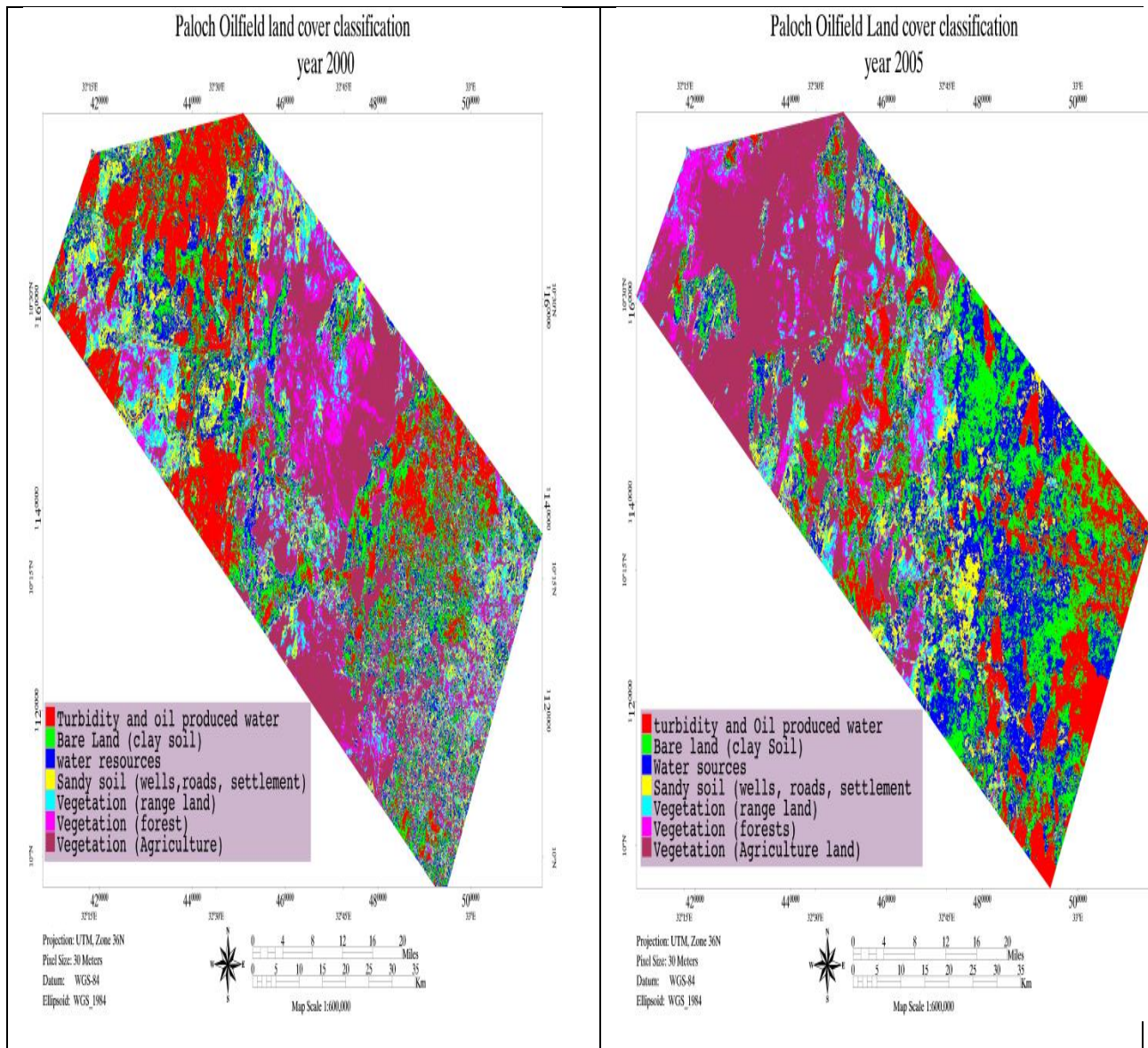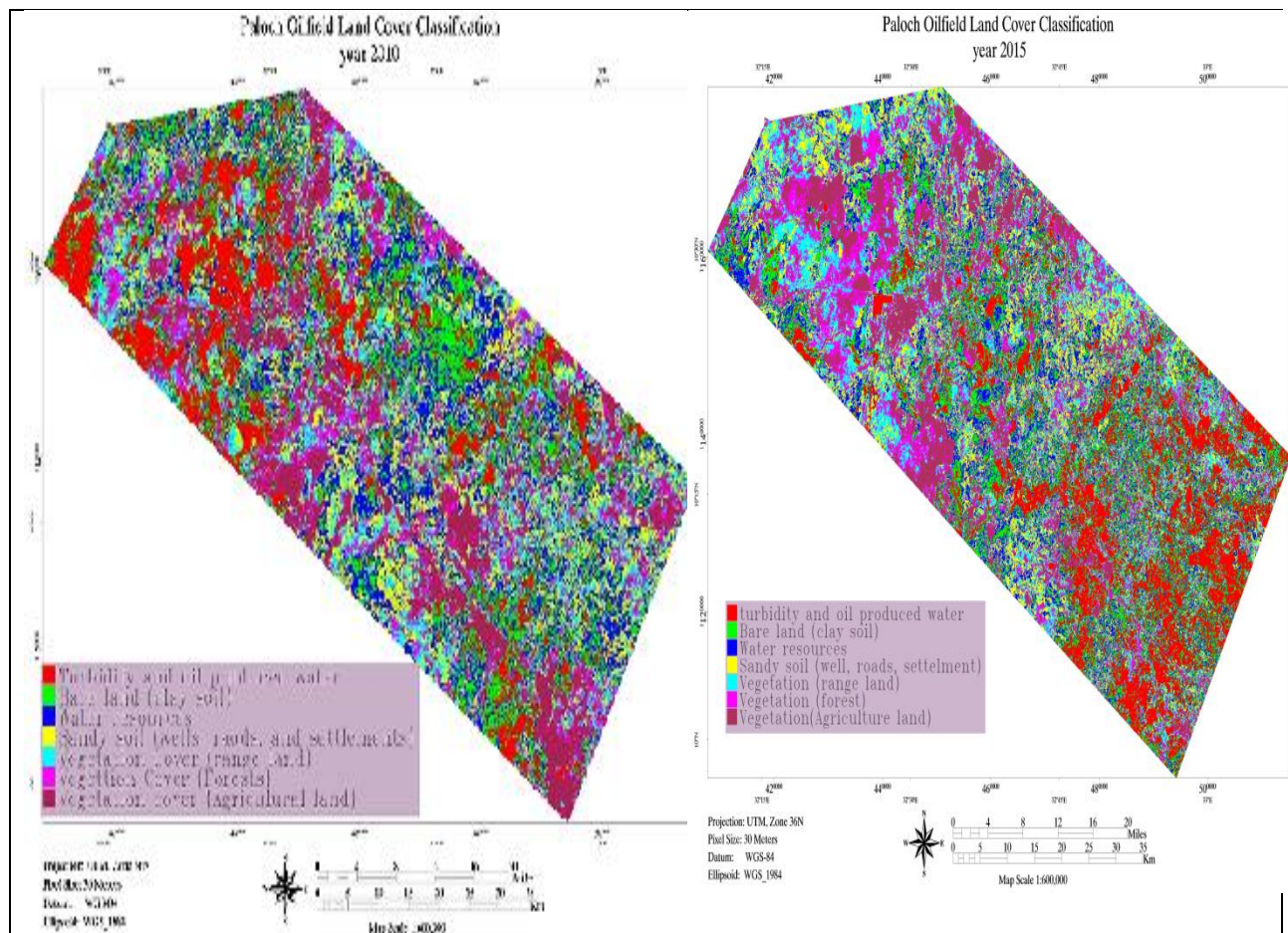**Fig (7) land cover classification from 2000 – 2015:**

Fig8: Relative changes in land cover 2000 – 2015:

Maps: Relative changes in land cover 2000, 2005, 2010 , 2015:

Conclusions:

The mass destruction of natural forests by petroleum exploitation and production in Paloch oilfield block 3 & 7 caused hazard to natural environment and land used systems. Natural forests and range land deteriorated and converted to wells surface and roads net work, agricultural land and settlement areas were affected and destructed by mining and production activities. In addition to that continuation of random digging holes and uprooting natural forest for oil well surface and roads without appropriate management, laws, rules, regulations and program to regulated and manage the mining and operation activities the hazard to the environment will increase, because the large area of natural forest, agriculture, grazing land and wild life habitat will be covered and destroyed by oil wells, roads and oil produced water pond.

Recommendations:

To overcome all these impacts and to achieve sustainable use of the natural resources oil and forest and to check the trend of the natural environment's deteriorations, the following are recommended;

- Close the patches forests areas in Paloch oilfield as reserve forests.
- Rehabilitation and plantation of affected natural forest areas by using treated oil produced water in irrigation.
- Incorporating community development based programs that include the compensations inform of building new

settlement areas with concrete materials to reallocate the natives who live within and around the oil wells recently
- Making clear assessment of the environmental impact of the oil industry in Southern Sudan.
- Treatment and reinjection of oil produced water in wells.
- Maintained and reorganized the chemical yard.
- Make used of natural gas instate of direct release and flaring.
- More research in field of oil and environment must be conducted.

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تقيم الأثر البيئي لتنقيب وتشغيل البترول على الغطاء النباتي و نظم استغلال الأراضي

(دراسة حالة حقل فلوج للنفط مربعي 3 و7) ملوط – ولاية شمال أعالي النيل- جنوب السودان

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المستخلص

أجريت هذه الدراسة للفترة ما بين 2015 – 2018م بحقل فلوج للنفط مربعي 3 و7 منطقة ملوط – ولاية شمال أعالي النيل– جنوب السودان. هدفت الدراسة الى تقييم الأثر البيئي للتنقيب و العمليات النفطية على البيئة الطبيعية بالإضافة الى التعرف على تاثيرها على نظم إستخدامات الأراضي و الخصائص الإقتصادية و الإجتماعية للمجتمعات المحلية و مدى تاثير تلك العمليات على صحة الإنسان ، الحيوان و التنوع الحيوي بمنطقة الدراسة خلال الفترة 2000– 2015. تم الحصول علي البيانات من خلال تحميل الصور الجوية من الأقمار الإصطناعية من خلال المسار/الصف 53/172: والمسار/الصف: 53/173 للسنوات 2000 ، 2005 ، 2010 و 2015 وتم معالجة هذه الصور وتصنيفها رقمياً من خلال استخدام تصنيف تحت الاشراف و آخر غير خاضع للاشراف . أظهرت نتائج التصنيف والتحليل أن المناطق ذات الغطاء النباتي تتناقص باستمرار من 41 % إلى 37 % من المساحة الاجماليه في الفترة بين 2000– 2005 ، بينما الخالية من الغطاء النباتي في زيادة مستمرة خلال هذه الفترة من 14 % إلى 20 %. وكان الانخفاض في الغطاء النباتي والزيادة في التربة الرملية نتيجة لأنشطة إستكشاف النفط واسعة النطاق داخل الغابات الطبيعية التي أزيلت لغرض إنشاء الطرق والآبار ومناطق الاستيطان. وقد تغيرت هذه النسب المئوية في الاتجاه خلال الفترة ما بين 2010–2015 حيث ظل الغطاء النباتي والتربة الرملية تقريباً نفس النسبة من 39 % إلى 40 % للغطاء النباتي أما تربة الأراضي الرملية قد زادت من 12 – 16% خلال الفترة 2000 – 2015م. ويرجع التغير إلى انخفاض أنشطة التنقيب عن النفط وانخفاض عدد السكان في المنطقة خلال هذه الفترة بسبب انعدام الأمن نتيجة للحرب الاهلية التي اندلعت خلال الفترة من 2013–2018م. حيث اختفت أنواع الحيوانات البرية من المنطقة المضطربة ، باستثناء القليل من الحيوانات و الأرانب والقرود التي تكيفت مع التدخلات البشرية في الغابات الطبيعية. وهاجرت أنواع أخرى من الحيوانات إلى المناطق الآمنة و بعض الدول المجاورة. أوصت الدراسة بأهمية بإستصلاح الغابات الطبيعية المتدهورة وإعادة إسترزاعها بجانب المحافظة علي الغابات الحالية ،كذلك أوصت الدراسة بضرورة تنظيم أنشطة و عمليات إنتاج النفط من خلال إشتراك المجتمعات المحلية ، بجانب إجراء المزيد من البحوث و الدراسات العلمية المرتبطة بدراسات تخفيف الأثر البيئي في المنطقة.