APPRAISAL OF FOREST CHANGES USING CHANGE DETECTION ANALYSIS IN ALSUNT FOREST KHARTOUM STATE OF SUDAN

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APPRAISAL OF FOREST CHANGES USING CHANGE DETECTION ANALYSIS IN ALSUNT FOREST KHARTOUM STATE OF SUDAN

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ABSTRACT

Effective geospatial monitoring of land use land cover changes particularly forest cover changes is necessary to overcome the degradation of the terrestrial ecosystem to further mitigate the effects of global climate change. Therefore, this research aims at mapping, estimating, and monitoring the forest cover changes in Alsunt forest of Sudan using geographical information system (GIS) and satellite-based approaches. This research was achieved by the following objectives to a) map and estimate the spatial extents of land use land cover in the study area; b) monitor the forest cover changes within the study site, and c) analyzed the forest cover changes using GIS tool and descriptive statistical techniques. The "Maximum Likelihood Classification (MLC)" technique was used to map the spatial extents of land use land cover (forest, water body, build-up areas, bear land, and agriculture) within the study sites and further estimate the distribution of the extents. The historical monitoring of the forest cover changes for 3 epochs (2000, 2010, and 2019) was accomplished using Landsat 8 Operational Land Imager (OLI) and Landsat 5 Thematic Mapper (TM). Whereas, the analyses of the forest cover change were achieved using descriptive statistical techniques. The results realised results are a) spatial distribution map and estimation of land use land cover changes; b) forest cover maps showing changes (hectares (ha))in the year 2000 (599153.3ha), 2010 (57778.38ha), and 2019 (34920.99ha); and c) analyses of the forest cover changes for the three epochs revealed R2 0.780, 0.857, and 0.891, p-value (0.005, 0.001, 0.001) and Root Mean Square Error (RMSE) ± 0.910, ± 0.510, and ± 0.620 for the year 2000, 2010, and 2019 respectively. Hence, this research shall serve as a guide for planning and management of forest conservation and restoration for sustainability and climate change mitigation.

ABSTRAK

Pemantauan geospatial yang efektif terhadap perubahan tutupan tanah penggunaan tanah terutama perubahan tutupan hutan diperlukan untuk mengatasi degradasi ekosistem darat untuk mengurangkan lagi dampak perubahan iklim global. Oleh itu, penyelidikan ini bertujuan untuk memetakan, menganggar, dan memantau perubahan tutupan hutan di hutan Alsunt di Sudan menggunakan sistem maklumat geografi (GIS) dan pendekatan berasaskan satelit. Penyelidikan ini dicapai dengan objektif berikut untuk a) memetakan dan menganggar luas spatial tutupan tanah penggunaan tanah di kawasan kajian; b) memantau perubahan tutupan hutan di lokasi kajian, dan c) menganalisis perubahan tutupan hutan dengan menggunakan alat GIS dan teknik statistik deskriptif. Teknik "Klasifikasi Kemungkinan Maksimum (MLC)" digunakan untuk memetakan luasan ruang penggunaan lahan (hutan, bayi air, kawasan penambangan, tanah beruang, dan pertanian) di dalam lokasi kajian dan memperkirakan pengedaran terbentang. Pemantauan sejarah perubahan tutupan hutan selama 3 zaman (2000, 2010, dan 2019) dilakukan dengan menggunakan Landsat 8 Operational Land Imager (OLI) dan Landsat 5 Thematic Mapper (TM). Manakala, analisis perubahan tutupan hutan dicapai dengan menggunakan teknik statistik deskriptif. Hasil yang direalisasikan adalah: a) peta taburan ruang dan anggaran perubahan tanah guna tanah; b) peta penutup hutan yang menunjukkan perubahan (hektar (ha)) pada tahun 2000 (599153.3ha), 2010 (57778.38ha), dan 2019 (34920.99ha); dan c) analisis perubahan penutup hutan untuk ketiga-tiga zaman itu menunjukkan R2 0.780, 0.857, dan 0.891, nilai p (0.005, 0.001, 0.001) dan Root Mean Square Error (RMSE) ± 0.910, ± 0.510, dan ± 0.620 untuk tahun 2000, 2010, dan 2019 masing-masing. Oleh itu, penyelidikan ini akan berfungsi sebagai panduan untuk merancang dan mengurus pemuliharaan dan pemulihan hutan untuk kelestarian dan mitigasi perubahan iklim.

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LIST OF ABBREVIATIONS

UTM	-	University Technology Malaysia
GIS	-	Geographic Information System
RS	-	Remote Sensing
LU	-	Land Use
LC	-	Land Cover
UN	-	United Nations
GCP	-	Ground Control Points
GPS	-	Global Position System
USGS	-	United State Geological Survey
IPCC	-	Intergovernmental Panel on Climate Change
REDD+	-	Reducing Emissions from Deforestation and Forest Degradation
RMSE	-	Root Mean Square Error
MLC	-	Maximum Likelihood Classification

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Mapping and estimation of forest cover changes are required to overcome forest degradation and deforestation, which are regarded as the second top roots of anthropogenic greenhouse (GHGs) emission followed by combustion of fossil fuel, this account for > 17% worldwide carbon dioxide (CO_2) emissions (Redowan *et al.*, 2019). Thus, forest degradation and deforestation have become a crucial issue relating to mitigation of climate change, emphasised in fourth Report Assessment in 2007 by the Intergovernmental Panel on Climate Change (IPCC). Around 75% of emissions were derived from tropical deforestation and forest degradation have been from developing countries containing large extents of tropical forest, including Brazil (Thangaperumal *et al.*, 2019). Global initiatives such as the "United Nations Framework Convention on Climate Change (UNFCCC)'s" program on "Reducing Emissions from Deforestation and Forest Degradation (REDD+) targeted at mitigating climate change through reducing forest cover losses and degradation (Mohd *et al.*, 2010).

Forests ecosystem, especially forest within the tropical humid, it shelters the main proportion of the terrestrial biological diversity (McGinley *et al.*, 2019) together with 80% estimated total terrestrial species, which cover 70 – 90% of above and belowground biomass (Connette *et al.*, 2016). These forests are regularly converted to industries, settlements, and plantations, critically reducing carbon storage and forest biodiversity (Runting *et al.*, 2019). The forest in the Khartoum state of Sudan is facing deterioration due to anthropogenic activities, desert encroachment and erosion (Abdelslaam, 2018). However, rapid conversion of land-use with agricultural activities has resulted in the natural forests cover removal and a corresponding biodiversity loss and forests carbon stock (Heilmayr *et al.*, 2020).

Degradation of the forest has been emphasized by the international forestry communities, with the "United Nations Forum on Forest (UNFF)", and the Target (2010) on the "Convention on Biological Diversity (CBD)" (Carrapatoso and Geck, 2018). The forest differs significantly in the forestry community across the globe due to differences in climatic factor (Fadrique *et al.*, 2018). Progress has been achieved also nominal definitions well-defined in the provision of monitoring in REDD objectives. Mapping and estimation of forest changes using satellite-based are less mature within the forest in Sudan. Indeed, the estimation of forest cover changes using a conversational approach is more difficult due to time and logistics related issues.

Recently, several studies have been carried out on forest changes due to deforestation, erosion, and other human activities using a geospatial method (Bera *et al.*, 2020; Fadrique, *et al.*, 2018). For a precise forest cover assessment to be succeeded, the future spatial distributions knowledge of the LU is required, and that could be achieved by using the information extracted using GIS and from the previous satellite-based images (Wu *et al.*, 2014). The ability to consider the dynamics of spatiotemporal of land use components is needed. Hence, it is essential to assess and monitor the historical changes of the forest cover to overcome the dynamic impacts of the changes.

Even though efforts have been invested by various studies on mapping land use and forests cover changes using geospatial methods (Aksoy and Kaptan, 2020; Hassan *et al.*, 2016). However, the majority of these studies were conducted elsewhere across the globe but are not reported in Sudan and to be specific in the forest of Khartoum state. Therefore, this study widens the scope by mapping, estimating, and monitoring the forest cover changes in Alsunt forest and its vicinity within the Khartoum state of Sudan using geographical information system (GIS) and satellite-based approaches. Realising the outcome of this research shall enable the achievement of the global pressing issue on protection, restoration and promotion of sustainable utilisation of terrestrial ecosystems, combat desertification, manages forests, and reverses biodiversity loss and land degradation disasters.

1.2 Problem Statement

Rapid growths in population and urbanization together with anthropogenic related activities such as deforestation are among the main contributors of climate change. These factors could affect the forests land use over time. Increment in population particularly in the capitals is of great worry to the sustainability of ecosystems around the globe. It is reported that 30% of the people in the world were dwelling in urban in 1950. This result to increase of > half (54%) in 2014 and with expectations that it could reach up to 66% by 2050 according to the UN (United Nations, 2014). Deforestation and soil erosion are the major factors affecting the study area due to the increase in population. The more people dwelling in an area the more pressures on resources affected the environment. Since the information on mapping and monitoring of forest cover changes are essentially required for terrestrial ecosystem management and conservation, thus, research in the domain remains an interesting topic, particularly in Sudan.

Currently, there are numerous methods of assessing land use/forest cover changes using the combination of remotely sensed data and geographical information system (GIS); since they provide time-series data and suitable techniques to analyze and form diverse scenarios that could be utilized for detecting changes in the forest. Studies have previously been made to assess forest land-use changes (Pal *et al.*, 2018; Persson *et al.*, 2017), from the spatial perspective, biomass/carbon estimation and temporal perspective (Batool *et al.*, 2015; Khan *et al.*, 2020). However, the majority of these studies were conducted elsewhere across the globe but rarely or none is reported on monitoring of forest cover changes using remotely sensed data and GIS in Alsunt forest, Khartoum state of Sudan. This research, therefore, mapped, estimated, and monitored the forest cover changes in Alsunt forest and its neighbourhood in the Khartoum state of Sudan using GIS and satellite-based approaches.

1.3 Research Questions

The questions of this research have been derived out of the objectives of the study:

(a) How can GIS and satellite imagery be used to map and estimate land use and land cover changes?

(b) To what extent the forest cover changes can be historically monitored in the study area?

(c) Which analysis can be utilised in forest cover changes examined in objective (b)?

1.4 Aim and Objectives

This research aims to assess the forest cover changes in Al-Sunut forest of Sudan using a geographical information system and satellite-based approaches. The specific objectives are as follows:

(a) To map and estimate the spatial extents of land use land cover changes in the study area.

(b) To monitor the forest cover changes within the study site, and

(c) To analyse the forest cover changes within the study area.

1.5 Scope of the Study

Geographically this research is limited to Al-Sunut forest, the Khartoum state of Sudan to be able to answer the questions set by this research and realised the targeted objectives. Therefore, the scope is determined by the following four elements:

(a) Study Area

(b) Data type

(c) The method used to execute the research

(d) Software and Hardware

1.5.1 Study Area

The research was carried out in Al-Sunut forest, Khartoum state of Sudan. This area is regarded as a natural forested situated within the Sudan capital in the centre of Khartoum (Figure 1.1). The site is bordered by the new White Nile Bridge from the North, the industrial area from the South, the Ghaba Street from the East and the White Nile from the West Sunut forest is severely stressed by human activities, especially construction. As a result of its exclusive location, the forest is largely stressed with extensive human activities, particularly constructions (Eltayeb *et al.*, 2012). Similarly, the Al-Sunut forest is considered by the sparse natural regeneration along with extensive tree fewer locations with seasonal flora and shrubby as reported by FNC. Historically, the initial plantation carried out in 1921, is located at the present ‘Al-Sunut Reserve Forest in Khartoum state, which was gazetted 11 years when it is founded in 15th July 1932.

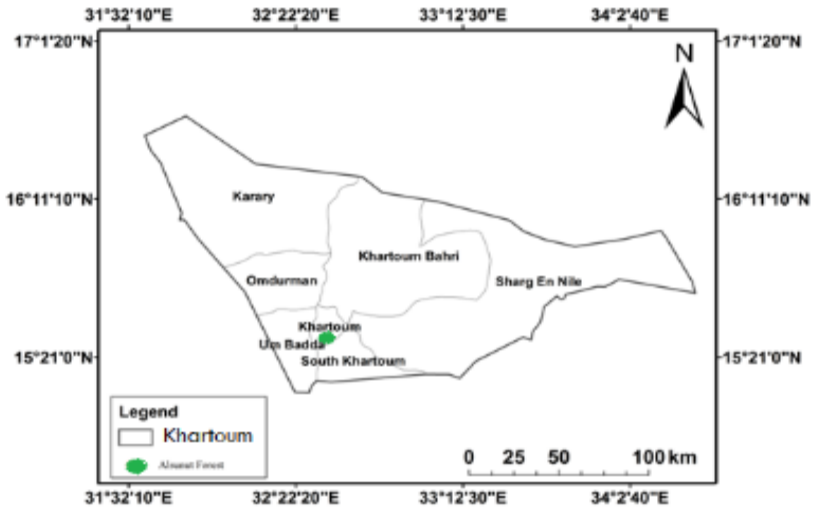

Figure 1.1 The Map of Al-Sunut forest, Khartoum state of Sudan (Source: Google Map)

1.5.2 Data

In this research, there two sets of data that were used to answer the objectives of the research. These set of data include satellite images and field measurement to identify the forest and non-forested areas using Global Positioning System (GPS) and Topographic map. The satellite data involves multi-temporal Landsat 8 images from 2000 to 2019, which were downloaded freely from Earth explorer, to realise the goal of this proposed research.

1.5.3 Brief Methodology

The research utilises data qualitative (GPS points) methodology to answer the research questions. Similarly, the methodology will constitute four phases as follows: The first phase describes data gathering of both primary and secondary data (Landsat images and GPS points). The second phase includes pre-processing, which was applied before performing the analysis. The third phase describes the processing using Maximum Likelihood Classification (MLC) to identify forest and non-forested areas within the study area. The fourth phase used change detection analysis to detect

changes within the study location. The software that was employed for pre-processing, processing and GIS analysis include ArcGIS 10.4, Envi5.3 and Microsoft office.

1.5.4 Software and Hardware

Numerous software was utilised at different phases of processing of data. For example, ArcGIS 10.4 and ENVI 5.3 were employed for image correction and image classification. Microsoft Excel was used for accuracy assessment and other descriptive statistical analysis. These packages of the software were selected based-on availability as well as high-quality performance. Whereas the hardware constitutes a laptop for drafting the entire, write-up and other related items.

1.6 Scope of the Study

The following are the scope of the study:

(a) Geographically, the study was conducted in Alsunt forest, Khartoum state of Sudan. Multi-temporal Landsat satellite images of Three periods (2000, 2010, 2019), Topographic maps, and Digital Elevation Model (DEM) was be used for detecting the long-term forest changes within the study area. The data were sourced from internet websites and other relevant secondary data sources.

(b) Supervise classification (Maximum Likelihood Classification) was utilized to distinguished the physical changes within the land use, while the forest cover changes were detected and analysed individual to show the level of the changes within the study area.

(c) Software's of several types were employed at different stages of processing. For instance, ArcGIS 10.4, and ENVI 5.3 were utilized during image enhancement/correction, image classification and generation forest changes

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