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LAND USE, LAND COVER CHANGE AND SOIL QUALITY INDICES IN AGRICULTURAL PRACTICES IN AL-BAYDA-LUSSAITAH, AL-JABAL AL-AKHDAR, LIBYA

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By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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October 2021

Chair : Associate Professor Siva K. Balasundram, PhD
Faculty : Agriculture

This research was conducted to explore the changes in the land use and land cover to advance our understanding of their potential effects on soil quality indicators under native land cover and farming systems in the region of Al-Jabal Al-Akhdar in the north-east of Libya through a case study in the area of Al-Bayda-Lussaitah, in the middle northern part of the region. This would be very essential for the management and preservation of soil resource and future land use planning. A Post-classification comparison approach has been employed for change detection analysis using four multi-temporal Landsat images from 1985, 2000, 2010, and 2017. A total number of 180 soil samples were collected in the summer of 2016 from three different land use and cover types (rainfed agriculture, irrigated crops, and forest) and analyzed to evaluate change effects on soil parameters and assess soil quality using an indexing approach.

The investigation outcomes highlight the importance of satellite digital image processing with the aid of GIS technology in mapping land use and land cover changes at the regional level. The changes observed in this study indicated a decline in the area of natural forest land, which lost 9,018 ha over 32 years (1985-2017), approximately 39% of its initial total area. Most natural forest losses were due to the conversion into rainfed and irrigated agricultural lands, which expanded over 4,095 and 2,266 ha, about 55% and 85% of initial areas, respectively. This was a consequence of increased food demand which requires opening new land for agriculture production mainly through deforestation. The highest deforestation rate was registered in the third period (2010-2017) at an estimated 513 ha $year^{-1}$, about the double of the rate in the second period (2000-2010) and three times that recorded in the first period (1985-2000). Indeed, if this present deforestation trend continues, the study area will lose more than 50% of its natural forest cover over the next 15 years. The present study indicated that converting forest into agricultural land uses and adapting unsuitable farming practices has a significant negative influence on most soil parameters leading to considerable land degradation and increased soil erosion as

observed in the study area due to the absence of protective vegetation cover, which makes soil surface directly exposed to erodibility factors. The negative influence of agricultural practices on soil properties suggests the need for intervention through sustainable land management procedures to sustain the soil quality in the native and cultivated land.

This study used three different indexing methods to evaluate the soil quality of native and agricultural lands (i.e., simple additive index, weighted functional index, and minimum dataset-based index) and suggested that using these methods can provide a similar pattern of results with the highest soil quality rating under the natural forest and the lowest in irrigated land. The results obtained from the three indexing methods revealed a significant decline in the soil quality of the cultivated lands relative to the reference soil under forest cover, estimated between 19-30 %. In general, the soil quality of agricultural land ranged from moderate to very low, whereas soil under forest cover was classified as high to very high quality. At least 75% of cultivated sites were subjected to great soil quality decline, which required improving the agricultural practices to improve soil quality and land productivity.

The study compared the performance of the three indexing methods and found perfect agreements and correlations among pairs of soil quality indices. The study concluded that principal component analysis could be used successfully for minimizing the number of soil quality indicators required to be measured in the subsequent investigations. Thus, the soil quality index based on the minimum data set of four soil quality indicators (i.e., organic matter, available phosphorus, electrical conductivity, and microporosity) was suggested as a superior index to predict overall soil quality in the region considering its perfect agreement and correlation with the other indices and capability to provide an effective assessment in terms of cost and time required for soil analysis and the ability to replicate over time due to the lower number of soil indicators that need to be measured. The adoption of this index would help farmers and producers to assess and monitor soil quality under the current land management, which can provide early alarm of land degradation so the required remediation or improvement measures can be implemented in due course. This strategy would sustainably improve food production by improving the quality of the current agricultural lands instead of opening new lands for agriculture through deforestation, thus preserving both agricultural and forest lands from degradation.

Abstrak tesis yang dikemukakan kepada Senat of Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

GUNA TANAH, PERUBAHAN LITUPAN BUMI DAN INDEKS KUALITI TANAH DALAM AMALAN PERTANIAN DI AL-BAYDA-LUSSAITAH, AL-JABAL AL-AKHDAR, LIBYA

Oleh

JAMAL S A BELKASEM

Oktober 2021

Pengerusi : Profesor Madya Siva K. Balasundram, PhD
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Penyelidikan ini dilakukan untuk meneroka perubahan guna tanah dan litupan bumi bertujuan unttuk meningkatkan pemahaman berkaitan potensi kesannya terhadap penunjuk kualiti tanah di bawah litupan tanah asli dan sistem pertanian di wilayah Al-Jabal Al-Akhdar di timur laut Libya melalui kajian kes di kawasan Al-Bayda-Lussaitah, di bahagain utara tengah wilayah itu. Ini sangat penting untuk pengurusan dan pemeliharaan sumber tanah serta perancangan guna tanah masa hadapan. Pendekatan perbandingan pasca-pengkelasan telah digunakan untuk analisis pengesanan perubahan menggunakan empat imej Landsat multi-temporal dari tahun 1985, 2000, 2010 dan 2017. Sebanyak 180 sampel tanah telah dikumpulkan pada musim panas 2016 dari guna tanah dan litupan tanah yang berbeza (pertanian tadah hujan, tanaman pengairan dan hutan), dan dianalisis untuk menilai kesan perubahan pada parameter tanah dan menaksir kualiti tanah menggunakan pendekatan pengindeksan.

Hasil penyelidikan mengetengahkan kepentingan pemprosesan gambar digital dengan bantuan teknologi GIS dalam memetakan perubahan guna tanah dan litupan tanah di peringkat wilayah. Perubahan yang diperhatikan dalam kajian ini menunjukkan penurunan di kawasan hutan alami yang kehilangan 9.018 hectares selama 32 tahun (1985-2017), sekitar 39% dari total luas awalnya. Sebilangan besar kehilangan hutan semula jadi disebabkan oleh penukaran menjadi lahan pertanian hujan dan pengairan, yang meluas di atas tanah pertanian baru yang dianggarkan 4.095 dan 2.266 hectares, masing-masing sekitar 55% dan 85% dari kawasan awal. ini adalah akibat peningkatan permintaan makanan yang memerlukan pembukaan lahan baru untuk pengeluaran pertanian terutama melalui penebangan hutan. Kadar penebangan hutan tertinggi dicatatkan pada tempoh ketiga (2010-2017) pada anggaran 513 hectares per year, kira-kira dua kali ganda kadar pada tempoh kedua (2000-2010) dan tiga kali ganda yang dicatatkan pada tempoh pertama (1985-2000). Sesungguhnya, sekiranya arah alir penyahhutanan berterusan, kawasan kajian akan kehilangan lebih dari 50% litupan hutan semulajadi dalam tempoh 15 tahun akan datang. Kajian ini menunjukkan bahawa

menukarkan hutan kepada guna tanah pertanian dan menyesuaikan amalan pertanian yang tidak sesuai mempunyai pengaruh negatif yang signifikan pada kebanyakan parameter tanah yang menyebabkan degradasi tanah yang agak signifikan dan peningkatan hakisan tanah seperti yang diperhatikan di kawasan kajian kerana tidak adanya penutup vegetasi pelindung yang membuat permukaan tanah secara langsung terdedah kepada faktor hakisan. Pengaruh negatif amalan pertanian terhadap sifat tanah menunjukkan bahawa perlunya intervensi melalui prosedur pengurusan tanah yang lestari untuk mengekalkan kualiti tanah di tanah asli yang diusahakan.

Kajian ini menggunakan tiga kaedah pengindeksan yang berbeza untuk menilai kualiti tanah tanah asli dan pertanian (iaitu, indeks aditif mudah, indeks fungsi berwajaran dan indeks berasaskan dataset minimum) dan mencadangkan bahawa penggunaan kaedah ini boleh memberikan corak hasil yang serupa dengan penarafan kualiti tanah yang tertinggi di kawasan hutan semula jadi dan terendah di tanah pengairan. Keputusan yang diperoleh daripada tiga kaedah pengindeksan menunjukkan penurunan ketara dalam kualiti tanah yang dianggarkan antara 19-30% di kawasan yang ditanam berbanding dengan tanah rujukan di kawasan litupan hutan. Sekurang-kurangnya 75% daripada tanah yang ditanam mengalami kemerosotan kualiti tanah yang agak tinggi. Kajian menunjukkan bahawa analisis komponen utama dapat digunakan dengan jayanya untuk meminimumkan bilangan penunjuk kualiti tanah yang perlu diukur dalam penyelidikan berikutnya. Oleh itu, indeks kualiti tanah berdasarkan set data minimum disarankan sebagai indeks unggul untuk meramal kualiti tanah secara keseluruhan di wilayah ini kerana memberikan penilaian masa dan keberkesanan kos.

Kajian ini telah membandingkan prestasi tiga kaedah pengindeksan dan mendapati persetujuan dan korelasi yang sempurna antara pasangan indeks kualiti tanah. Kajian ini merumuskan bahawa analisis komponen utama boleh digunakan dengan jayanya untuk meminimumkan bilangan penunjuk kualiti tanah yang diperlukan untuk diukur dalam melaksanakan penyiasatan seterusnya. Oleh itu, indeks kualiti tanah berdasarkan set data minimum empat penunjuk kualiti tanah (iaitu bahan organik, kandungan fosforus, kekonduksian elektrik dan mikroporositi) telah dicadangkan sebagai indeks unggul untuk meramal keseluruhan kualiti tanah di rantau ini dengan mengambil kira persetujuan yang sempurna dan korelasi dengan indeks lain, keupayaan untuk memberikan penilaian yang berkesan dari segi kos dan masa yang diperlukan untuk analisis tanah serta keupayaan untuk mereplikasi dari semasa ke semasa disebabkan oleh bilangan penunjuk tanah yang lebih rendah yang perlu diukur. Penggunaan indeks ini akan membantu petani dan pengeluar menilai dan memantau kualiti tanah di bawah pengurusan semasa dengan memberi amaran awal tentang kemerosotan tanah supaya langkah pemulihan atau penambahbaikan yang diperlukan dapat dilaksanakan dalam masa terdekat. Strategi ini akan meningkatkan pengeluaran makanan secara mampan dengan menambah baik kualiti tanah pertanian semasa dan mengelakkan pembukaan tanah baru untuk pertanian melalui penebangan hutan, dan dengan itu dapat memelihara kedua-dua tanah pertanian dan hutan daripada degradasi.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Declaration by the Members of Supervisory Committee

This is to certify that:

- The research conducted and the writing of the thesis was under our supervision;
- Supervision of responsibilities as slated in Rule 41 in Rule 2003 (Revision 2012-2013) were adhered to.

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ANOVA	Analysis of Variance
AWHC	Available water holding capacity
BD	Bulk density
BLV	Bare and low vegetation areas
BR	Basal respiration
$CaCO_3$	Calcium carbonate
CEC	Cation exchange capacity
DOS	Dark Object Subtraction
EAJA	Executive Authority for Al- Jabal Al-Akhdar
EC	Electrical conductivity
EROS	Earth Resources Observation and Science Center
ETM+	Enhancement Thematic Mapper Plus
FA	Factor analysis
FAO	Food and Agriculture Organization
GCP	Ground Control Point
GPS	Global positioning system
ha	Hectare
IC	Irrigated crops
ISSS	International Society of Soil Science
K_{av}	Available potassium
km	Kilometre
K-S	Kolmogorov-Smirnov test
K_{sat}	Saturated hydraulic conductivity
L5	Landsat 5

L7	Landsat 7
L8	Landsat 8
LGAC	Landsat Global Archive Consolidation)
LULC	Land use and land cover
MDS	Minimum data set
MDS-SQI	Soil quality index based on the minimum data set
ML	Maximum likelihood
MP	Macro porosity
NMF	Natural Mediterranean forest
NNDiffuse	Nearest neighbor diffusion
NO_3-N	Nitrate nitrogen
NQI	Nemoro quality index
OLI	Operational Land Imager
OR	Orchards and rainfed agriculture
Pav	Available phosphorus
PCA	Principal component analysis
pH	power of hydrogen (measure of acidity or alkalinity)
RSD	Resisting surface structure degradation
SA-SQI	Simple additive soil quality index
SCP	Sustain crop productivity
SLC	Scan line corrector
SMAF	Soil Management Assessment Framework
SOM	Soil organic matter
SQI	Soil quality index
SSSA	Soil Science Society of America
TM	Thematic Mapper

TOA	Top-Of-Atmosphere
TP	Total porosity
UB	Urban and built-up lands
UNDP	United Nations Development Program
USDA	United States Department of Agriculture
USGS	U.S. Geological Survey
WE	Water entry
WF-SQI	Weighted functional soil quality index
WMA	Water movement and availability

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The land is an essential natural resource as it is the habitation of flora and fauna and where economic, social, infrastructure and other human activities are exercised. Thus, various changes have taken place in land use and land cover (LULC) in the previous years (Angassa et al., 2012), where the term "land cover" refers to all the physical features of the immediate land surface whether natural or manmade, and the term "land use" refers to the human activities correlated with a particular unit of land, in terms of use, influence or management practices (Mas, 1999). These changes are ongoing and are probable to continue in the future similar to population growth and increased demand for assorted products and may lead to positive or negative effects, with the latter being the primary concern of the world as they affect human well-being and safety (Bieling et al., 2013).

Many studies showed that only a few landscapes on earth, in peripheral sites and remote locations, remain in their natural state (Tilman & Lehman, 2001; Gupta et al., 2017). The rapid increase in world population, which causes an increase in anthropogenic activities, has resulted in speedy LULC alteration which led to widespread forest deterioration and loss of fertile lands which were transformed to urban construction with significant effects on the ecosystem and threats to food security, livelihood systems, and earth resources sustainability (Guan et al., 2011; Al-Sharif & Pradhan, 2014). LULC change is a vital expression of human interactions with the environment and is characterized and affected by a plethora of factors in time and space at different magnitudes. These factors include natural, political, socioeconomic, cultural, among many other factors (Gupta et al., 2017). The earth surface transformation management is one of the persistent world ecological challenges to be addressed in this century, mainly due to LULC changes (Ayele et al., 2018). Presently, understanding and mapping of LULC changes have occupied an important position in policy-making regarding the management of natural resources and monitoring of environmental changes.

Conversion of undisturbed natural forest for other land uses such as agriculture can lead to significant and long-term impacts on soil quality and productivity. Despite the different effects of land use and management on the soil properties among soil types and ecological regions, it is generally conceded that their changes have a significant role in exacerbating the issue of soil erosion and land degradation. Many works of literature have documented that the closest consequences of deforestation and intense land utilization for agriculture purposes are directly or indirectly linked to the concerns of soil quality deterioration, decreases in biodiversity, and accelerated soil loss by erosion (Girmay et al., 2008; Gelaw et al., 2014, 2015a), which are known to be the most serious problems threatening the sustainability of land productivity and food security in the world (Rowntree & Fox, 2008; Ries, 2010). Land degradation has become one of the major environmental issues all over the world and influences both developed and developing nations (Romm, 2011).

The Mediterranean region has been influenced by anthropic disruption for thousands of years and is, currently, one of the most significantly altered hotspots in the world (Sluiter & de Jong, 2007). In general, there are two processes of LULC change are occurring in the Mediterranean regions during the last decades; the first process is the decline in rainfed agriculture and forest uses and the second process is the intensification of irrigated crops and the urbanization of coastal plains (Saurì & Breton, 1998; Serra et al., 2008). The primary causes for the first process lie in the abandonment of agriculture for social and economic reasons, whereas the latter is connected to agricultural intensification and tourism development (Saurì & Breton, 1998). Land degradation processes are expected to worsen as a result of climate change and intensified land use. Therefore, understanding the dynamics of LULC and exploration of driving biophysical and anthropological factors of change are considered a significant research priority (Sluiter & de Jong, 2007).

Libya, the second-largest country of the Mediterranean basin with a total surface area of 1.75 million km^2 (Figure 1.1), is characterized by huge variability in geological, climatic, and biological assets and has been subjected to various anthropogenic activities carried out by various peoples and cultures over millennia, which have influenced local landscapes and preserved natural biodiversity (OMU, 2005). It is widely known that Libya, like other developing nations, encounters serious LULC change problems, principally due to its rapidly growing population that raised the need to increase food production through opening new lands for cultivation (Aburas, 2009; Alsoul, 2015). In a country with limited water and land resources, this will be a major challenge in the coming decades. As Libya's population and ambitions grow, the land becomes increasingly scarce. The growing demand for food and fodder coupled with inadequate areas suitable for agricultural production to meet the demands have resulted in a transformation of large forest and range lands for agricultural expansion, even to marginal lands and steep slopes. This is widely common in many parts of Libya and was often the reason for the devastation of limited natural vegetation cover and a the emergence of soil degradation and accelerated erosion problems (Ben-Mahmoud et al., 2003; OMU, 2005). Since there is a lack of sufficient supervision and intervention to regulate the expansion of agricultural land in unsuitable locations, increased loss of fertile soil from farmed and sloping lands due to erosion and other degradation processes has become a major environmental concern in Libya. The growing and competitive demand for land, either for agricultural production or any other purpose, need to make decisions that will ensure the optimum use of the limited land resources. Consequently, agricultural development institutions must ensure that the land does not deteriorate, maintain its quality, and enhance its capacity to meet the human needs of present and future generations. Therefore, the evaluation of soil quality under current agricultural uses and the identification of soil degradation causes are essential when planning for rational land utilization and sustainable management of natural resources.

The Al-Jabal Al-Akhdar region, with its privileged location in northeastern Libya and overlooking the Mediterranean Sea, is no exception from the dynamics of LULC change and land degradation. The region has the highest precipitation (400-650 mm) in Libya; it comprises areas of intensive cultivation in the plains and lengthways at the bottoms of the valleys and natural forest and shrubland on steep canyons and Terra Rosa slopes. The region constitutes only 1% of Libya’s total area; however, it is a regional hotspot of Mediterranean biodiversity, including 90% of the country's forest (Abdlrahman, 2011),

and is considered the only natural forest in the space between Lebanon in the east and Tunisia in the west (Al-Zeni & Bayoumi, 2006). The region is regarded as one of the most important agricultural zones of the country in the production of vegetables, grains, and many kinds of fruit that provides a large part of the requirements for food supply to residents in the region and other parts of the country. The area is suitable for agricultural investment, which is relatively limited in the region and depends mainly on changing the land use pattern from natural vegetation cover (Mediterranean Maquis) to different types of agricultural investment (rainfed or irrigated agriculture). Despite the economic and social return of this investment, they may have environmental impacts on soil characteristics in the short or long term (OMU, 2005). In the Al-Jabal Al-Akhdar area, the conversion of natural forest land to low-input farming systems has been extensive. Thus, much soil erosion is expected to have occurred in the area over the last few decades.

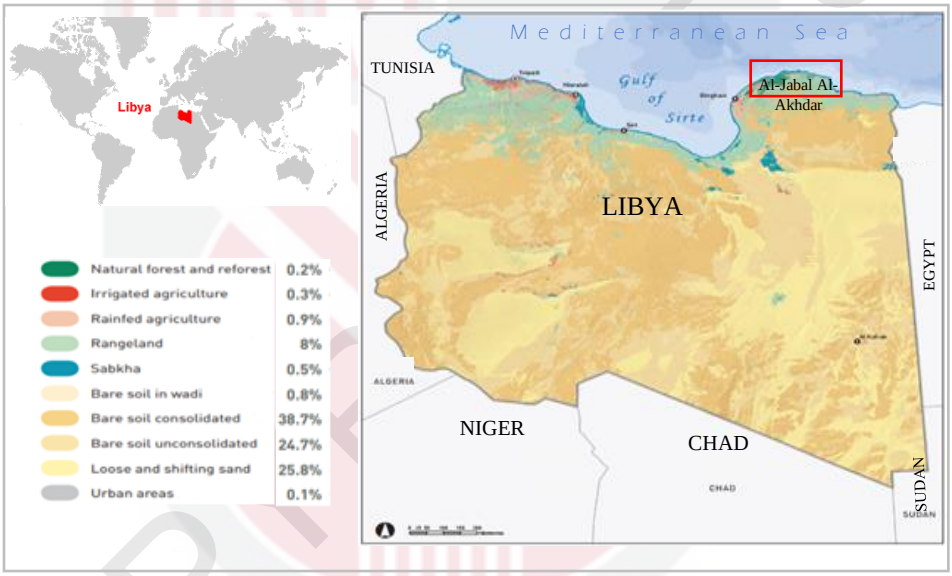

Figure 1.1: Aggregated land cover map of Libya (Source: FAO and UNDP, 2009)**.**

Like other developing countries, the agriculture system in the region of Al-Jabal Al-Akhdar is largely a smallholder farming system and characterized by high spatial and temporal variability in the selection of cultivated crops which usually depend upon the markets, practiced technologies, the spread of pests, government support, potentials of investment, etc. (Altieri, 2009). Furthermore, the agriculture production in the region depends on the timely onset, duration, amount, and distribution of precipitation which makes the sector extremely vulnerable to drought and other climate conditions. On the other hand, due to the indiscriminate spread of new settlements, the conversion of parts of the agricultural lands in these regions into built-up areas for commercial, residential, or industrial uses frequently results in scattered urban sprawl. This pattern of unplanned change deteriorates the quality of agriculture and urban environments for the citizens (Arsanjani et al., 2011; Al-Shalabi et al., 2013; Arnous, 2013).

Soil quality preservation under different land uses is essential in strengthening the quality and productivity of crops sustainably even under severe environmental conditions in arid and semi-arid areas such as the region of Al-Jabal Al-Akhdar, where the occurrence of high soil erosion and decline nutrient level is prevalent. Soil quality assessment has been proposed as a valuable method for determining whether or not the soil and farming practices are sustainable (Prabhavathi et al., 2013). It is well known that soil quality evaluation through measuring individual soil parameters may not reflect the real status of soil quality. Thus, using an integrated index to combine soil properties can provide a more accurate assessment and an indication of soil quality than evaluating individual parameters (Dick, 1994; Elliot, 1994), which is required for identifying areas with productivity problems, making faithful estimation of food production, monitoring changes in sustainability and environmental quality concerning farming management systems, and providing government agencies with valuable information for evaluating and redesigning policies related agriculture and other land-use sustainability (Granatstein & Bezdicek, 1992). In fact, there is no widely accepted method to assess soil quality because of the large complexity and diversity of the soil system. Much remains to be understood regarding the complexity of the relationships between specific soil parameter measurement quality and the overall soil quality.

Anthropogenic activities and other environmental factors have recently increased the pressure on available land resources in the Al-Jabal Al-Akhdar area. During the years following the Libyan revolution in 2011, the region has witnessed dramatic rapid LULC changes. Due to the breakdown of the Al-Qaddafi regime in 2011 and the proliferation of weapons, the situation in the region of Al-Jabal Al-Akhdar became very dangerous and represents a serious, direct threat to the natural forest as many people in various places have benefited from the chaos and cleared thousands of hectares of natural forest land for various purposes including the conversion to agricultural use and building construction. On the other hand, the area of Al-Jabal Al-Akhdar is struggling with another serious problem: urban sprawl on natural forests and agricultural land. The native ecosystem is constantly changing over large areas, and there is no national monitoring program to keep track of it. Collectively, these changes to landscape surface are the most sensitive subject required to be addressed considering the scarcity of fertile lands and the importance of the forest in the region being the only natural vegetation in the country.

In response to the increase in human pressure on the limited resources of the arable land and forest, the changes have resulted in LULC and land management. These developments, as well as management activities that do not consider soil care measures, have had a significant impact on some important soil resources, such as on the degradation of soil quality and decline the land productivity of large areas, as well as many ecological imbalances in the region of Al-Jabal Al-Akhdar. In the Al-Jabal Al-Akhdar area, a decrease in natural vegetation cover and disruption of the native ecosystem has resulted in extensive soil degradation, with a consequent reduction in soil organic matter (SOM) content which is considered an essential indicator for declining soil quality (OMU, 2005). The over-exploitation of the soils over years has led to the debilitation of agricultural production systems, and a steady decline in productivity has been observed in different parts. Moreover, in recent years, the available land resources have been put under more pressure from anthropogenic activities and other environmental factors. The dramatic quick LULC changes that occurred in the region of Al-Jabal Al-Akhdar exacerbated the problem of land degradation after 2011. Changes

are happening continuously over vast areas and without a national program for monitoring.

1.2 Problem Statement in the Study Area

This study was motivated by the lack of up-to-date information about the dynamic of LULC change in the region, particularly in the last years. This makes detecting LULC change fundamental to show the magnitude and severity of danger to which the limited land resources in Libya are exposed. Therefore, this study tried to benefit from using remote sensing and GIS technologies, as practical tools for accurate and cost-effective multispectral and multi-temporal data, for analyzing LULC changes at different spatiotemporal scales besides clarifying factors behind these changes.

The study was also motivated by the fact that despite the widespread awareness of the issue of land degradation under cultivation system, as well as concern about the fate of forest lands been converting and will continue to be converted to agricultural activity following inappropriate land management practices, most land degradation research works conducted in Libya generally and the region of Al-Jabal Al-Akhdar particularly have often focused on soil erosion or study some individual soil properties in isolation from other aspects of soil management. Therefore, conducting a comprehensive analysis of soil under agricultural systems and comparison with the original condition under non-destructive soils would be essential for the management and preservation of soil resources and future land use planning.

Although the assessment of overall soil quality and determination of its key indicators is important and has become popular in different regions of the world, the review of the research literature has shown that such study has never been conducted in the region of Al-Jabal Al-Akhdar as well as in the whole country. Therefore, the current study was intended to fill this literature gap by evaluating the overall quality of soil under agricultural and forest cover in the study area and developing an effective, simple systematic assessment method suitable for application in the region of Al-Jabal Al-Akhdar, which is highly needed for early detection of soil degradation, so that proper actions can be taken in the right time to improve soil quality and maintain sustainable land productivity.

1.3 Objectives of the Study

1.3.1 General Objective

This study aimed to investigate changes in LULC management systems and advance our understanding of their potential effects on soil quality indicators in farming systems by comparing the native forestry and land use types in the Al-Jabal Al-Akhdar region of northeastern Libya. The case study area is Al-Bayda - Lussaitah, located in the middle of the northern part of the region.

1.3.2 Specific Objectives

To achieve the general objectives set out above, the study is structured around the following four specific goals:

1. To detect and assess temporal and spatial LULC changes that have taken place in the study area using remote sensing and geographic information system (GIS) techniques and analyze the underlying forces behind change processes.

2. To investigate and assess the influences of the cultivation of deforested land on the individual chemical, physical, and biological soil properties as potential soil quality indicators.

3. To apply different integrated soil quality indices to estimate the overall soil quality of agriculture and forest lands in the study area and evaluate its change in response to the current farming practices.

4. To propose a suitable systematic method and a minimum data set of key indicators that allow a quick, cost-effective estimation of the soil quality at a regional scale.

1.4 Significance of the Study

Land use and land cover change is the aspect that could be the cause in land degradation and biodiversity loss over time. Hence, stakeholders, people, and communities concerned must pay more attention to the undesired impact of land-use alteration. Therefore, the existing geographic information is a critical component required to be considered when designing development plans, particularly in marginal ecosystems such as the Al-Jabal Al-Akhdar region. Maintaining the greenery of the terrain in this area is critical. Furthermore, forest cover has an essential role in soil stabilization and climate change mitigation. This research is anticipated to assist specific parties such as the Al Jabal Al Akhdar district office, the Forest Department, and other authorities in monitoring LULC change in the region.

The widespread occurrence of soil quality and land productivity decline in the region of Al-Jabal Al-Akhdar is believed to be caused by land-use change. Proper soil management and land use are required to mitigate the problem. Farmers should be aware of the consequences of poor soil management. Hence, detecting and assessing LULC changes and monitoring their effects on soil quality in the region of Al-Jabal Al-Akhdar are very important for understanding the dynamics of LULC changes and how soil quality indicators respond to those changes, which would be essential for the management and preservation of soil resource, and future land use planning. Planners and decision-makers require reliable and up-to-date spatiotemporal information on previous and current LULC and the status of soil quality indicators to judge what is the most sustainable land-use system. Such information would help optimize the use of the land surface by elaborating rational management options and suggesting the relevant remedial and conservation measures that endeavor to maintain essential landscape functions and sustain the land productivity (Fallahzade & Hajabbasi, 2012).

Conducting a comprehensive soil analysis in developing countries like Libya is challenging due to the high expenses and a lack of facilities and technology. Therefore, developing a practical and effective soil quality index in terms of cost and time is critical for application by investigators, environmental monitors, resource managers, and decision-makers to determine the sustainability of soil and crops under different land uses.

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