UNIVERSITI PUTRA MALAYSIA

RANGELANDS RESTORATION ANALYSIS IN SOUTHERN AL-JABAL AL-AKHDAR, LIBYA USING LANDSCAPE FUNCTION ANALYSIS AND SELECTED VEGETATION INDICES

ADEL M. A. MAHMOUD

RANGELANDS RESTORATION ANALYSIS IN SOUTHERN AL-JABAL AL-AKHDAR, LIBYA USING LANDSCAPE FUNCTION ANALYSIS AND SELECTED VEGETATION INDICES

By

ADEL M. A. MAHMOUD

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

July 2016

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

RANGELANDS RESTORATION ANALYSIS IN SOUTHERN AL-JABAL AL-AKHDAR, LIBYA USING LANDSCAPE FUNCTION ANALYSIS AND SELECTED VEGETATION INDICES

By

ADEL M. A. MAHMOUD

July 2016

Chairman : Associate Professor Mohd Hasmadi Bin Ismail, PhD
Faculty : Forestry

Many regions in Libya have begun to show signs of rangelands degradation, the major causes of which are drought and overgrazing. It has been documented that rangelands deterioration has led to a reduction in the variety of plants and a decrease in yield, and this decreases the regenerative capacity of rangeland ecosystem. This study was conducted on the southern slope of Al- Jabal Al- Akhdar, northeast Libya. The main objective was to assess shrub rangeland recovery to determine whether or not exclosures (fenced areas) are an effective method or strategy for the restoration and rehabilitation of rangelands at the regional level.

Four research areas with moderate to severe degraded soil and vegetation, namely Madur Zetun, Omguzlan, Thahar Altair, and Ajramiah, were selected along a strong north-south rainfall gradient, which include a diverse range of soil and vegetation types. A total of 28 monitoring sites were re-installed and assessed between May and December 2014. These sites were initially installed and assessed between May and December 2006. The monitoring sites were installed within the exclosures and in open rangelands for grazing. The monitoring layout is based on the Western Australia Rangeland Monitoring System (WARMS). In order to achieve the research objective, Landscape Function Analysis technique (LFA) and selected Vegetation Indices (VIs) were employed.

The outcomes of the LFA field data calculations show that the ecosystem function increased positively with the increase in rehabilitation time of the protected areas where fences is taking places. The results also indicate an increase in the three indices of soil surface condition (SSI, WII and NCI) inside the fenced rangelands. The findings demonstrate a good linear relationship between the LFA-SSA indices and the selected Vegetation Indices. NDVI (Normalized Difference Vegetation Index) and MSAVI (Modified Soil-Adjusted Vegetation Index) were closely correlated to the field data.

Additionally, the results indicate that the vegetation cover did not change or increase in a large portion of the regions under study even with 80% of the study area still under severe to very severe conditions of degradation. Finally, estimates show that a period of 10 years, meant to protect the vegetation from animal grazing may be needed in the higher rainfall location at the north (Maduar Zetun). Regions that experience low rainfall situated in the south prior to the recovery of vegetation, and soil surface condition at the time of grazing, require a long period of protection. Grazing must be controlled to facilitate the conservation and rehabilitation of rangeland natural resources.

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

ANALISIS PEMULIHAN PADANG GEMBALA DI SELATAN AL-JABAR AL-AKHDAR, LIBYA MENGGUNAKAN FUNGSI ANALISIS LANDSKAP DAN INDEKS TUMBUHAN TERPILIH

Oleh

ADEL M.A. MAHMOUD

Julai 2016

Pengerusi : Profesor Madya Mohd Hasmadi Bin Ismail, PhD,
Fakulti : Perhutanan

Banyak wilayah di Libya telah mula menunjukkan tanda-tanda degredasi padang gembala. Antara penyebab utama degredasi ini adalah kemarau dan ragutan lampau. Terdapat rekod yang menunjukkan bahawa kemerosotan padang gembala telah menyebabkan penurunan dalam keanekaan tumbuh-tumbuhan dan pengurangan hasil, dan ini mengurangkan kapasiti jana semula ekosistem padang gembala. Kajian ini telah dijalankan di cerun selatan Al-Jabar Al-Akhdar, timur laut Libya. Objektif utama kajian ini adalah untuk menilai pemulihan pokok renek padang gembala bagi memastikan sama ada exclosures (kawasan berpagar) adalah kaedah atau strategi efektif untuk pemulihan semula dan rehabilitasi padang gembala pada peringkat wilayah.

Empat kawasan kajian dengan tanah dan vegetasi pada tahap degredasi sederhana hingga teruk, iaitu Madur Zetun, Omguzlan, Thahar Altair, dan Ajramiah, telah dipilih sepanjang utara-selatan kecerunan taburan hujan yang banyak, yang turut mempunyai pelbagai jenis tanah dan vegetasi. Sebanyak 28 tapak pengawasan telah dipasang semula dan dinilai dari bulan Mei hingga Disember 2014. Tapak pengawasan ini pada asalnya dipasang dan dinilai antara bulan Mei dan Disember 2006. Tapak pengawasan ini dipasang dalam *exclosure* dan di padang gembala terbuka untuk ragutan. Pelan susun atur tapak pengawasan didasarkan kepada Sistem Pengawasan Padang Gembala Australia Barat (SPPGAB). Untuk mencapai objektif kajian, teknik Analisis Fungsi Lanskap (AFL) dan Indeks Vegetasi (IV) terpilih telah digunakan.

Hasil kiraan data lapangan AFL menunjukkan bahawa fungsi ekosistem meningkat secara positif seiring dengan peningkatan masa rehabilitasi untuk kawasan terpelihara berpagar. Keputusan turut menunjukkan peningkatan dalam tiga indeks keadaan permukaan tanah (kestabilan, penyusupan, dan nutrien berkitaran) dalam kawasan padang gembala berpagar. Keputusan juga menunjukkan hubungan linear yang baik

antara indeks AFL-SSC dan Indeks Vegetasi terpilih. IVPT (Indeks Vegetasi Perbezaan Ternormal) dan IVTTT (Indeks Vegetasi Tanah-Terlaras Terubah suai) berkolerasi rapat dengan data lapangan.

Di samping itu, keputusan menunjukkan penutup vegetasi tidak berubah atau meningkat dalam kebanyakan kawasan yang dikaji, walaupun 80% kawasan kajian masih berada pada tahap keadaan degredasi yang teruk hingga sangat teruk. Akhirnya, anggaran kajian ini menunjukkan bahawa jangkamasa 10 tahun, untuk memelihara vegetasi daripada ragutan haiwan, mungkin diperlukan di lokasi taburan hujan tinggi di utara Libya (Maduar Zetun). Kawasan yang mengalami taburan hujan rendah yang terletak di selatan sebelum pemulihan vegetasi, termasuk keadaan permukaan tanah pada masa ragutan, memerlukan jangka masa pemeliharaan yang lama. Ragutan mesti dikawal untuk memudahkan pemuliharaan dan rehabilitasi sumber asli padang gembala.

ACKNOWLEDGEMENTS

In the Name of Allah, Most Gracious, Most Merciful, all praise and thanks are due to Allah, and peace and blessings be upon His Messenger. I would like to express the most sincere appreciation to those who made this work possible: Advisory members, Friends and Family.

I would like to thank Associate Professor, Dr. Mohd Hasmadi Bin Ismail for providing me the opportunity to complete my PhD studies under his valuable guidance, for the many useful advice and discussions, for his constant encouragement and guidance, and for co-authoring and reviewing some of my publications, where her practical experience and technical knowledge made this research and those publications more interesting and relevant. In addition, special thanks are extended to the supervisory committee member; Associate Professor. Dr. Mohamad Azani Bin Alias and Dr. Alias Bin Mohd Sood. I am grateful for their willingness to serve on my supervisory committee, constant encouragement, helpful advice and many fruitful discussions.

My thanks also go to the coordinator of graduate studies in the Faculty of Forestry Professor. Dr. Zaidon Ashaari for the moral and intellectual support, and Professor Dato' Dr. Nik Muhamad Majid who accepted my proposal and allowed me to study in the UPM. I wish to thank Dr. Khalid Rehman Hakeem who helped me with some advices that facilitated the publication.

Thanks and acknowledgements are meaningless if not extended to my father's spirit and mum who deserve my deepest appreciation. I am grateful for the countless sacrifices they made to ensure that I could pursue my dreams and for always being there for me. Real and deepest thanks to them. May ALLAH bless them, all praise and thanks words said to them will not be enough.

And last but not the least, I wish to thank my University (University of Omar Al-Mukhtar, El Beida, Libya) and my country Libya for their contributions in my study either directly or indirectly. I would also like to thank the Universiti Putra Malaysia and the beloved country Malaysia for their hospitality and generosity.

I certify that a Thesis Examination Committee has met on 22 July 2016 to conduct the final examination of Adel M. A. Mahmoud on his thesis entitled "Rangelands Restoration Analysis in Southern Al-Jabal Al-Akhdar, Libya using Landscape Function Analysis and Selected Vegetation Indices" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

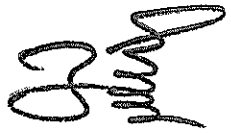
Members of the Thesis Examination Committee were as follows:

Mohd Zaki bin Hamzah, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Helmi Zulhaidi bin Mohd Shafri, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohammad Firuz bin Ramli, PhD
Associate Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Internal Examiner)

Tamaki (Itaya) Akemi, PhD
Associate Professor
Mie University
Japan
(External Examiner)



ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 23 August 2016

This thesis was submitted to the Senate of the 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:

Mohd Hasmadi Bin Ismail, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Mohamad Azani Bin Alias, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Member)

Alias Bin Mohd Sood, PhD
Senior Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Member)

_____
BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work
- quotations, illustrations and citations have been duly referenced
- the thesis has not been submitted previously or comcurrently for any other degree at any institutions
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be owned from supervisor and deputy vice –chancellor (Research and innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software

Signature: _____ Date: _____

Name and Matric No: Adel M.A. Mahmoud, GS37887

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature:	
Name of Chairman of Supervisory Committee:	Associate Professor Dr. Mohd Hasmadi Bin Ismail
Signature:	
Name of Member of Supervisory Committee:	Associate Professor Dr. Mohamad Azani Bin Alias
Signature:	
Name of Member of Supervisory Committee:	Dr. Alias Bin Mohd Sood

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AJ	Ajramiah area
ARLC	The Libyan Agricultural and Livestock Research Centre
CE	Commission Error
CLFA	Calibrated Landscape Function Analysis
CTVI	Corrected Transformed Vegetation Index
DPSIR	Driving Factors, Pressures, and States on land degradation
DN	Digital Number
DVI	Difference Vegetation Index
EFA	Ecosystem Function Analysis
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agricultural Organization
GIS	Geographic Information System
GLCN	Global Land Cover Network
HSRS	Hyperspectral Remote Sensing
KC	Kappa Coefficient
LADA	Land Degradation Assessment in Dry Lands
LRMS	Libyan Rangeland Monitoring System
LFA	Landscape Function Analysis
LOI	Landscape Organization Index
MSAVI	Modified Soil Adjusted Vegetation Index
MZ	Maduar Zetun area
NCI	Nutrient Cycling Index
NDVI	Normalized Difference Vegetation Index
NIR	Near Infra-Red Band
OE	Omission Error
PA	Producer accuracy
PDP	Pasture Development project
PSR	Perennial Species Richness Index
PVI	Perpendicular Vegetation Index
R	Red Band

REIP	Red Edge Inflection Point
RGR	Relative Growth Rate
RVI	Ratio Vegetation Index
SAVI	Soil Adjusted Vegetation Index
SCF	Structure, Composition and Function indicator
SFSTM	The Structural Functional State and Transition Model
SSA	Soil Surface Assessment
SSC	Soil Surface Condition
SSCI	Soil Surface Condition index
SWECO	Swedish Environmental Consultancy
SSI	Soil Stability Index
TA	Total Accuracy
TPA	Total Patch Area
TSAVI	Transformed Soil Adjusted Vegetation Index
TT	Thahar Altair area
TTRP	Trigger Transfer Reserve Pulse
TTVI	Thiam's Transformed Vegetation Index
TVI	Transformed Vegetation Index
UA	User Accuracy
UTM	Universal Transverse Mercator
VIs	Vegetation Indices
WARMS	Western Australia Rangeland Monitoring System
WDVI	Weighted Difference Vegetation Index
WII	Water Infiltration Index

CHAPTER 1

INTRODUCTION

1.1 Background

A rangeland is any area of land that is occupied by native herbaceous or shrubby vegetation, which is grazed by domestic or wild herbivores. The vegetation of rangeland may include tall grass prairies, steppes (short grass prairies), desert shrublands, shrub woodlands, savannas, and tundra. Temperate and tropical forests that are used for grazing can also be considered rangelands (Britannica, 2014). Rangelands are important resources that support the national economy. They are an essential foundation that support and develop the animal products industry. Sustainable and renewable if tended to properly, rangelands can cover an area of over 37.5 million km^2 or almost 61% of all dry lands in the world. However, land areas considered as rangelands vary from 18% to 80% (Lund, 2007; Middleton and Thomas, 1997). The most common form of land utilization activities in arid and semi-arid rangelands is ranching (Middleton and Thomas, 1997). Rangelands offer infrastructure for two main industries including the meat industry, which supplies food for many people around the world, and the wool industry, which utilizes sheep wool. In regard to semi-arid areas, rangelands provide an opportunity for socio-economic activities because they support pastoralist culture and the economy (Conner et al., 2001; Svoray et al., 2013). Nevertheless, in spite of their relevance, rangelands are still under constant threat from human encroachment, erosion, wearing, and the effects of drought.

The process of degradation in African rangelands is a result of human practices and changes in climate; about 31% of rangelands and 19% of forests and woodlands on the continent are considered degraded lands (Kapalanga, 2008). Erosion and exposure to chemical and physical damage have degraded 65% of agricultural land. Previously, overgrazing was cited as a major factor influencing degradation on the African continent. The degradation rate of Mediterranean steppes in North Africa is 1% per year, and this correlates to a high rate of degradation (Le Houerou, 2000; Le Houerou, 2001). Rangelands present in the western part of North Africa are found in the region between the Sahara desert and marine coastal areas where harsh conditions prevail over the environment. Low and erratic rainfall, high temperatures with high rates of evaporation, and shallow and poor soils characterize the environmental conditions in these regions. Management of the aforementioned rangelands in terms of sustainable forage production remains a major challenge.

Libya is an area that spans 1.7 million km^2; 148,330 km^2 is rangeland and 3,380 km^2 is forest and woodland (Figure 1). There is privatization of production, with some projects owned by the government, including irrigation of cereals and production of forage in arid regions. In North East Libya, the South Al-Jabal Al-Akhdar Project, initiated in 1973, is still on going and is currently referred to as the 'Pasture Development Project' (PDP). This major governmental project has attempted to

improve the condition of large areas of rangelands through a variety of strategies including seasonally-controlled grazing, construction of numerous check dams, digging of channels, establishment of cereal and fodder farms, and substantial associated infrastructure such as houses, roads, electricity, wells, and irrigation. More recently, the project has protected at least 6,000ha from grazing and has re-planted or reforested much of this area.

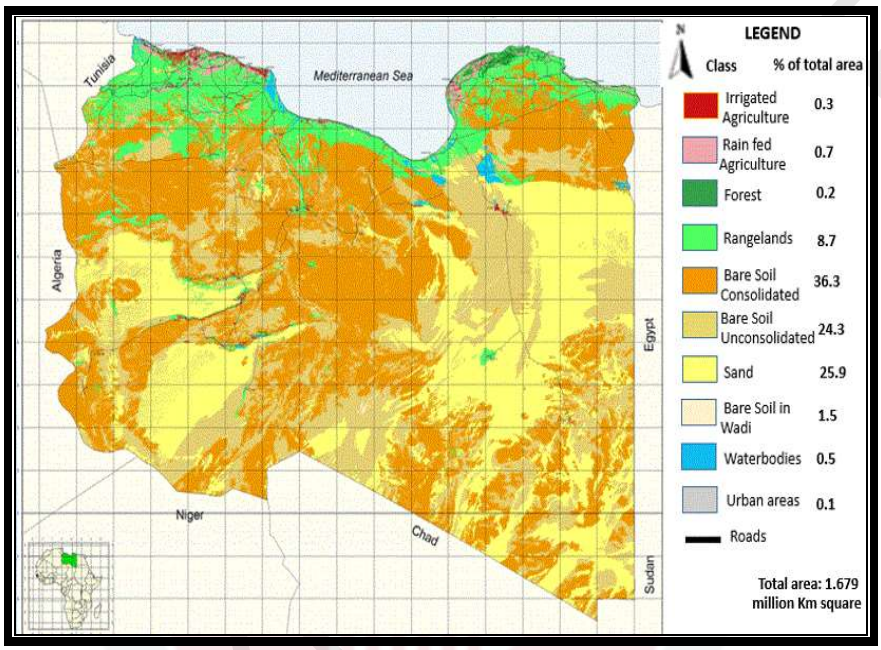


Figure 1. Land Cover and Vegetation Map of Libya
(GLCN, 2010)

As mentioned in the last line of the previous paragraph, the Pasture Development Project has established a series of fenced, protected areas known as exclosures, many of which are planted with exported species. There are also exclosures where natural vegetation recovery is allowed to occur. In 2006, 28 monitoring sites were installed and assessed inside and outside selected exclosures. This provides an opportunity to assess and analyze rangeland recovery and degradation within areas protected from grazing, as well as open areas for grazing.

1.2 Importance of the Study

Approximately 90% of the area occupied by Libya is desert, with the exception of the Al-Jabal Al-Akhdar region and the coastal strip. Al-Jabal Al-Akhdar (the green mountain) is a range in northeastern Libya in Cyrenaica, a province long renown for verdant mountains, a spectacular Mediterranean coastline, and well-preserved ancient Greek architecture. The mountain is the highest range in northern Libya and forms a broad promontory in the Mediterranean Sea, bound to the west by Wadi Al Bab and the east by the Bay of Bombah (SWECO, 1986).

According to the World Conservation Monitoring Center, the total species number of existing plants tends to 2059. These plants cannot be categorized as rich flora when compared to the country at large. The Maquis is the natural existing vegetation that occupies the Al-Jabal Al-Akhdar region. Even though the Al-Jabal Al-Akhdar region covers almost 1% of the entire area of Libya, it is still the richest part of the country with respect to biodiversity. There are over fifty percent of total plant species present in this region, making up 1100 different plant species, 75 of which are endemic (El-Darier and El-Mogaspi, 2009). It should also be noted that this region is home to a variety of medicinal and aromatic types of flora (Eldoumi et al., 2002).

1.3 Significance of the Study

This study used quantitative assessment methods for evaluating the effectiveness of exclosures (fenced areas) in rangeland restoration by assessing vegetation and soil condition inside and outside the exclosures. The study provided updated and documented information which will help the decision makers to take appropriate decisions regarding rangeland rehabilitation and conservation. The moral of this research lies in the continuity of previous work carried out in the region and a reference for future studies. The study may also be helpful in improving vegetation regeneration and developing strategies in order to eventually implement the exclosures as sustainable utilization.

1.4 Problem Statement

Many factors and human activities have caused rangeland degradation, leading to significant changes in landscape and original flora of the southern Mediterranean countries over the past 100 years (Le Houerou, 2000; Zatout, 2014). These activities include overgrazing, deforestation, inappropriate agricultural practices, fire, urban expansion, and industrial activities. However, the overgrazing factor has had the strongest effect on degradation (Figure 2). All the above-mentioned activities have led to destruction of native flora and has caused an increase in blowing sands and emissions of dust.

In the south Mediterranean area, overgrazing and wind erosion are the main reasons of desertification. Also, incorrect policies regarding control of desertification have paradoxically increased the amount of area prone for desertification. These policies have also delayed recovery of degraded land. About 12,672 km^2 of the Libyan rangelands are considered to be degrading areas, in which about half a million people are affected (Bai et al., 2008). Sheep, goats, and camels extensively graze the southern slope of Al-Jabal Al-Akhdar rangelands. Severely degraded soil and vegetation are widespread (Gebril and Saeid, 2012; Mahmoud et al., 2008). The amount of grazing animals in the region is considered so large that the natural rangeland areas cannot provide the livestock with its full forage requirements. The number of grazing animals has increased rapidly from 119,800 in 1980, to 152,930 in 2008 (Abdalrahman et al., 2010).

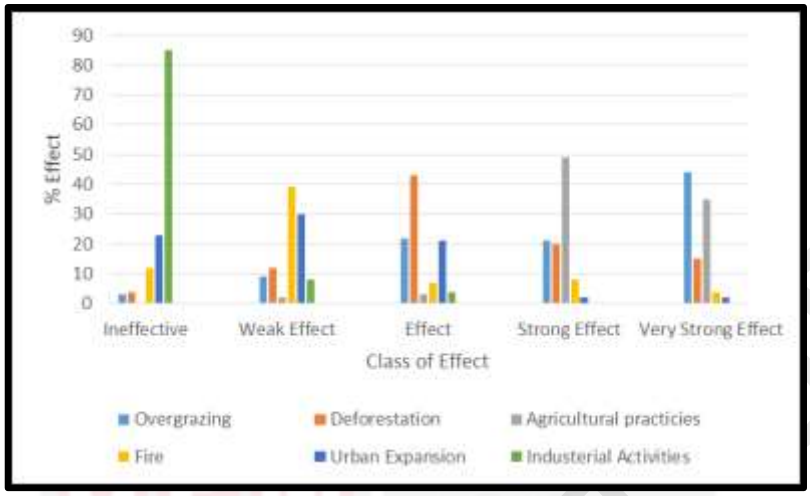


Figure 2. The Factors That Affect Vegetation Cover in Al-Jabal Al-Akhdar
(Abdalrahman et al., 2010)

The ecosystem of Al-Jabal Al-Akhdar is considered at risk of desertification due to Libya's prevalent climatic conditions, but the rangelands that are situated to the south of the Al-Jabal Al-Akhdar zone are still in pristine state and so self-sustainable such that the area can deal with minor ecosystem problems (Zatout, 2014). Degradation effects worsen due to processes that arise as a result of inappropriate or unsustainable land use practices, eventually resulting in very substantial, near permanent decline in ecosystem health and productivity. In a thoroughly comprehensive study, SWECO (Swedish Environmental Consultancy) reported that pasture yield in the Al-Jabal Al-Akhdar rangelands falls somewhat below the average of the Mediterranean Basin (SWECO, 1986). At the time, the measured productivity in terms of carrying capacity and forage biomass energy yield for 1986 and forecast productivity improvement in 15 years (by 2001) subject to the SWECO range management plan was set to be implemented. Unfortunately, the plan did not follow through and much of the rangelands continued to be utilized unsustainably resulting in continued soil and vegetation degradation. Forage Production was found to be very low in the grazing areas compared with the exclosures in the Al-Jabal Al-Akhdar rangelands (18.69 and 6.66 gm/m^2 respectively), as reported in one notable research conducted in 2006 (Sanosi, 2008).

Signs of desertification in the Al-Jabal Al-Akhdar rangelands include marked reduction or complete loss of vegetation cover, accelerated soil erosion, and increased frequency of dust storms, edaphic drying, reduced biodiversity, reduced habitat diversity, and reduced primary productivity (crop yield, animal productivity). The principle behind this is that the natural vegetation cover is being degraded and specific ecosystems become highly susceptible to further degradation. Hence, major effort to conserve and reestablish the natural vegetation in the Al-Jabal Al-Akhdar rangelands is called for. It has been documented that the deterioration and degradation of land quality has led to a decrease in the growth of palatable plant varieties; ultimately they become extinct. Consequently, due to the ongoing reduction in the variety of plants and

a decrease in yield, a disparity is created and this decreases the regenerative capacity of an ecosystem. So, the ecosystem finally reaches a stage where the changes are irreversible and then gradually ceases to exist. Rangeland management is crucial in the control of animal grazing and in achieving the maximum integration of both supply and regulation of ecosystem services.

As mentioned in the background, 28 monitoring sites were installed in the study area to produce a considerable amount of information and data base, useful in monitoring the desertification process in the Libyan rangeland. In regard to the project's development, it is necessary to mention that gaps of eight years are unacceptable. Although, the project was intended to be a long term continuous monitoring, the data base was never utilized until the date of this research. Therefore, through the use of this data base, the intention is to fill these gaps. One of these gaps is represented by the fact that remote sensing was never applied in the southern Al-Jabal Al-Akhdar rangelands, in particular, for grazing analyses.

1.5 Objectives of study

This study aims to monitor and assess shrub rangeland recovery in the southern slope of the Al-Jabal Al-Akhdar rangelands to determine whether or not exclosures (fenced areas) are an effective method or strategy for the regeneration and rehabilitation of rangelands. From the main objective, the following specific objectives are formed:

1- To investigate changes in perennial plants, landscape function, and soil surface condition in open grazing and protected areas.
2- To quantify the recovery rate of perennial plant cover in rangelands in the study area.
3- To assess selected Vegetation Indices for mapping the degradation status of rangelands.
4- To assess the ability of selected Vegetation Indices for predicting landscape function indices.
5- To propose rehabilitation and conservation strategies for the study area.

1.6 Scope and Limitations

The southern slope of the Al-Jabal Al-Akhdar experience a strong north-south rainfall gradient and contain a variety of land systems (vegetation – soil – landform associations). Three main revegetation techniques are presently used in the region in areas protected from grazing (exclosures), namely, tree planting (plantations), shrub replanting and natural vegetation recovery. The research strategy was to undertake comparative study of selected exclosures and open areas for grazing in order to document the difference in rangeland condition. It is principally a quantitate study of measurable plant and soil attributes, but also produced comprehensive supporting material (Peter, 2006). Four areas have been selected so as to encompass:

- Rainfall gradient from about 250mm per year in the north to less than 50mm in the south.

- Shrub replanted and natural vegetation recovery techniques.
- Soil types from upland, stony reddish brown loam to light brown silty desert loam on the low flat alluvial plains.
- Vegetation formations from dwarf shrub steppe to stem and leaf succulents steppe.

The study focus was principally on the lower rainfall zones where revegetation is technically more difficult. Here only shrub replanting and natural vegetation recovery techniques are practiced, and it is in these areas that PDP Authority has the most difficultly in convincing local communities to adopt sustainable land use practices (controlled grazing), and the benefits of protecting areas from grazing. In the higher rainfall zone closer to the catchment divide, tree replanting is successfully practiced without much technical difficulty and local community acceptance is much higher. In the future, it is anticipated that the PDP will progressively incorporate more exclosures to the east within the PDP Authority management region. Selection of these exclosures will probably utilize the same criteria given above.

The research was structured initially as two complementary parts. Each part is self-contained and manageable study in three years, but each part was contributed to the overall research objective and linked to the other. The two component parts are:

1- Landscape Function Analysis (LFA).
This study aimed to document differences in landscape functioning (macro-scale nutrient and water capture process) and soil surface condition (SSC) between exclosures and open areas for grazing. It entailed detailed measurements of landscape and soil surface attributes at numerous transects monitoring sites, data analysis and interpretation.

2- Remote sensing technology.
The goal of this part was to assess and map rangeland degradation on south slope of Al-Jabal Al-Akhdar region using satellite imagery and Geographic Information System (GIS).

The research has proceeded well, despite unavoidable and considerable limitations.
Firstly, the number of monitoring sites installed in 2006 (28 sites in four locations) is smaller compared to the overall study area. The impact of this limitation was reduced by analyzing the data for each sub-study area. As such, for future studies, the number of monitoring sites should be increased in order to insure that there is a limited level of experimental errors.

The second limitation is the exclosure's management, where the rangeland is not protected completely and, in some situations, the grazing animals can be observed inside a fenced area. However, this was not a frequent encounter.

Another inherent limitation to the study was the time, as the work field had to be performed in limited time, according to the study area in Libya and the University in Malaysia. Also, data regarding rainfall and temperature during the period between 2006 and 2014 was not found. As such, this limitation was solved by using the general trend of the rainfall in the study area, as well as the changes encountered within the map of Precipitation in Africa. This information revealed that there were no changes in the study area regarding the rainfall (Appendix F1).

REFERENCES

Abdalrahman, Y., Spence, K., and Rotherham, I. D. 2010. The main causes of direct human-induced land degradation in the libyan Al-Jabal Alakhdar region. *End of Tradition?*, pp. 8: 7. Sheffield Hallam University.

Anari, P., and Heshmati, G. 2009. Calibration of landscape function analysis method in an arid cold-season rangeland ecosystem in central part of Iran (case study: Mazraeamin rangeland, yazd province). *Iranian Journal of Range and Desert Research* 16: 386-400.

Anderson, G., Hanson, J., and Haas, R. 1993. Evaluating landsat thematic mapper derived vegetation indices for estimating above-ground biomass on semiarid rangelands. *Remote sensing of Environment* 45: 165-175.

ARC-ICARDA. 2008. Partnership between the Libyan Agricultural Research Center (ARC) and the International Center for Agricultural Research in the Dry Areas (ICARDA).

Ata Rezaei, S., Arzani, H., and Tongway, D. 2006. Assessing rangeland capability in Iran using landscape function indices based on soil surface attributes. *Journal of arid environments* 65: 460-473.

Aubault, H., Webb, N. P., Strong, C. L., McTainsh, G. H., Leys, J. F., and Scanlan, J. C. 2015. Grazing impacts on the susceptibility of rangelands to wind erosion: The effects of stocking rate, stocking strategy and land condition. *Aeolian Research* 17: 89-99.

Bai, Z., Dent, D., Olsson, L., and Schaepman, M. Global assessment of land degradation and improvement identification by remote sensing. *FAO/ISRIC-Rome*. 2008.

Bannari, A., Morin, D., Bonn, F., and Huete, A. 1995. A review of vegetation indices. *Remote sensing reviews* 13: 95-120.

Baret, F., and Guyot, G. 1991. Potentials and limits of vegetation indices for lai and apar assessment. *Remote sensing of environment* 35: 161-173.

Bartley, R., Roth, C. H., Ludwig, J., McJannet, D., Liedloff, A., Corfield, J., Hawdon, A., and Abbott, B. 2006. Runoff and erosion from australia's tropical semi-arid rangelands: Influence of ground cover for differing space and time scales. *Hydrological Processes* 20(15): 3317-3333.

Bastida, F., Moreno, J. L., Hernández, T., and García, C. 2007. Microbial activity in non-agricultural degraded soils exposed to semiarid climate. *Science of the total environment* 378: 183-186.

Bastin, G. N., Ludwig, J. A., Eager, R. W., Chewings, V. H., and Liedloff, A. C. 2002. Indicators of landscape function: Comparing patchiness metrics using remotely-sensed data from rangelands. *Ecological Indicators* 1: 247-260.

Bernstein, R., Colby, C., Murphrey, S., and Snyder, J. 1983. Image geometry and rectification. *Manual of remote sensing* 1: 873-922.

Bertiller, M. B., and Carrera, A. L. 2015. Aboveground vegetation and perennial grass seed bank in arid rangelands disturbed by grazing. *Rangeland Ecology & Management* 68: 71-78.

Bidgoli, R. D., Pessarakli, M., Heshmati, G. A., and Najafabadi, M. Y. 2012. Comparing ecological functions of eastern and southern slopes of a rangeland ecosystem in chaharbagh region, golestan province, Iran. *Journal of Environmental Science and Engineering* 1: 403-409.

Blanco, L. J., Ferrando, C. A., and Biurrun, F. N. 2009. Remote sensing of spatial and temporal vegetation patterns in two grazing systems. *Rangeland ecology & management* 62: 445-451.

Brinkmann, K., Dickhoefer, U., Schlecht, E., and Buerkert, A. 2011. Quantification of aboveground rangeland productivity and anthropogenic degradation on the arabian peninsula using landsat imagery and field inventory data. *Remote Sensing of Environment* 115: 465-474.

Britannica. Rangeland. N.D. Retrieved 11 April 2014 from https://global.britannica.com/science/rangeland.

Brooks, N. 2006. Cultural responses to aridity in the middle holocene and increased social complexity. *Quaternary International* 151: 29-49.

Chang, X., Bao, X., Wang, S., Wilkes, A., Erdenetsetseg, B., Baival, B., Avaadorj, D.-o., Maisaikhan, T., and Damdinsuren, B. 2015. Simulating effects of grazing on soil organic carbon stocks in Mongolian grasslands. *Agriculture, Ecosystems & Environment* 212: 278-284.

Chauhan, B. S. 2012. Weed ecology and weed management strategies for dry-seeded rice in asia. *Weed Technology* 26: 1-13.

Chen, F., and Weber, K. T. 2014. Assessing the impact of seasonal precipitation and temperature on vegetation in a grass-dominated rangeland. *The Rangeland Journal* 36: 185-190.

Chen, J., Jönsson, P., Tamura, M., Gu, Z., Matsushita, B., and Eklundh, L. 2004. A simple method for reconstructing a high-quality ndvi time-series data set based on the savitzky–golay filter. *Remote sensing of Environment* 91: 332-344.

Chen, Y. Correlation of saltbush cover measurements to tm wavebands and vegetation indices. Geoscience and Remote Sensing Symposium, IN IGARSS Proceeding, Hamburg, Germany Jun 28 - Jul 2, 1999 IEEE.1999

Chillo, V., Ojeda, R. A., Anand, M., and Reynolds, J. F. 2015. A novel approach to assess livestock management effects on biodiversity of drylands. *Ecological Indicators* 50: 69-78.

Clevers, J. 1988. The derivation of a simplified reflectance model for the estimation of leaf area index. *Remote Sensing of Environment* 25: 53-69.

Conner, R., A. Seidl, L. VanTasssell, and N. Wilkins. "United States Grasslands and Related Resources: An Economic and Biological Trends Assessment, Texas Aand M University, Institute of Renewable Natural Resources, 2001.

Crippen, R. E. 1990. Calculating the vegetation index faster. *Remote Sensing of Environment* 34: 71-73.

De Villalobos, A. E., and Peláez, D. V. 2015. Functional responses of woody prosopis caldenia seedlings to drought and livestock grazing in semiarid rangelands of Argentina. *Arid Land Research and Management* 29: 487-502.

Deering, D., and Rouse, J. 1975. Measuring'forage production' of grazing units from landsat mss data. *International Symposium on Remote Sensing of Environment 10*: 1169-1178.

Derbel, S., Cortina, J., and Chaieb, M. 2009. Acacia saligna plantation impact on soil surface properties and vascular plant species composition in central Tunisia. *Arid Land Research and Management* 23: 28-46.

Di Giovanni, E., and Palombini, A. 2002. Desertification, sustainability, and archaeology: Indications from the past for an african future. *Origini: Preistoria e protostoria delle civiltà antiche* 24: 303-334.

Di Lernia, S., Bertolani, G. B., Castelli, R., Merighi, F., Palombini, A., di Lernia, S., and Manzi, G. 2002. A regional perspective: The surveys. Sand, stones and bones: the archaeology of death in the Wadi Tannezzuft Valley, pp.25-68. Rome: Universita Deglistudi Di Roma.

Dregne, H. E. 1983. Desertification of arid lands, pp. 1-18. New York: Taylor and Francis.

Dunwoody, E., Apan, A., and Liu, X., Effects of spatial resolution on measurement of landscape function using the landscape leakiness calculator, In Proceedings of the Surveying and Spatial Sciences Conference, Canberra, Australia, April 17 - 19, 2013. SSSC. 2013).

Ehsani, S. M., Heshmati, G., and Tamartash, R. 2015. Effect of some environmental factors on plant distribution using LFA method (case study: Valuyeh summer

rangeland of mazandaran province). Journal of Biodiversity and Environmental Sciences 6: 62-68.

El-Darier, S., and El-Mogaspi, F. 2009. Ethnobotany and relative importance of some endemic plant species at Al-Jabal Al-akhdar region (Libya). *World Journal of Agricultural Sciences* 5: 353-360.

Eldoumi, F., Elsaedi, O., and Zunni, S. A. 2002. Study of Aljabal Alakhdar's plant cover (in Arabic). University of Omar Al- Mokhtar. Elbaida, Libya.

Eldridge, D. J., Beecham, G., and Grace, J. B. 2015. Do shrubs reduce the adverse effects of grazing on soil properties? Ecohydrology 8: 1503-1513.

Food and Agriculture Organization of the United Nation. Development of Tribal Lands and Settlements Project. FAO: Rome.1969.

Fernández, N., Paruelo, J. M., and Delibes, M. 2010. Ecosystem functioning of protected and altered mediterranean environments: A remote sensing classification in doñana, spain. *Remote Sensing of Environment* 114: 211-220.

Furniss, D. G. 2009. Can indices of landscape function analysis (LFA) be derived from ground-based spectroscopy? A case study from gold mines on the highveld of South Africa, Master Thesis, University of the Witwatersrand.

Gadallah, A. 2014. The effect of drought and grazing on the destrubution of perinnial plant cover in southern Al-Jabal Al-Akhdar rangelands, libya (in arabic). *International Journal for Environment & Global Climate Change* 2: 236-245.

Gaitán, J. J., Bran, D., Oliva, G., Ciari, G., Nakamatsu, V., Salomone, J., Ferrante, D., Buono, G., Massara, V., and Humano, G. 2013. Evaluating the performance of multiple remote sensing indices to predict the spatial variability of ecosystem structure and functioning in Patagonian steppes. *Ecological indicators* 34: 181-191.

Gamoun, M., and Hanchi, B. 2014. Natural vegetation cover dynamic under grazing-rotation managements in desert rangelands of Tunisia. *Arid Ecosystems* 4: 277-284.

Gao, B.-C. 1996. Ndwi—a normalized difference water index for remote sensing of vegetation liquid water from space. *Remote sensing of environment*, 58: 257-266.

García-Gómez, M., and Maestre, F. T. 2011. Remote sensing data predict indicators of soil functioning in semi-arid steppes, central Spain. *Ecological Indicators* 11: 1476-1481.

Gebril, A. , Saeid, A. 2012. 'Importance of Pastoral Human Factor Overloading in Land Desertification: Case Studies in Northeastern Libya. International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering 6: 688 - 693.

Ghiloufi, W., Perez, J. L. Q., Garcia-Gomez, M., and Chaieb, M. 2015. Assessment of species diversity and state of stipa tenacissima steppes. Turkish Journal of Botany 39:227-237

Global Land Cover Network (GLCN). Mapping of natural resources for agriculture use and planning in Libya. Retrieved 14 May 2014 from http://www.glcn.org/activities/libya_en.jsp.

Guo, K. 1996. Study on the general technique of improving degraded natural grassland. *Pratacultural Science* 13: 24-28.

Hagen, S. C., Heilman, P., Marsett, R., Torbick, N., Salas, W., Van Ravensway, J., and Qi, J. 2012. Mapping total vegetation cover across western rangelands with moderate-resolution imaging spectroradiometer data. *Rangeland Ecology and Management* 65: 456-467.

Hall, R., Skakun, R., Arsenault, E., and Case, B. 2006. Modeling forest stand structure attributes using landsat etm+ data: Application to mapping of aboveground biomass and stand volume. *Forest Ecology and Management* 225: 378-390.

Hall, T. J., McIvor, J. G., Reid, D. J., Jones, P., MacLeod, N. D., McDonald, C. K., and Smith, D. R. 2014. A comparison of stocking methods for beef production in northern Australia: Pasture and soil surface condition responses. *The Rangeland Journal*, 36: 161-174.

Hamad, S. M. 2012. Status of water resources of Al Jabal Al Akhdar region, North East Libya. Libyan Agriculture Research Centre Journal 3: 247-259.

Han, J., Zhang, Y., Wang, C., Bai, W., Wang, Y., Han, G., and Li, L. 2008. Rangeland degradation and restoration management in China. *The Rangeland Journal* 30: 233-239.

Han, Y., Wang, Y., and Zhao, Y. 2010. Estimating soil moisture conditions of the greater changbai mountains by land surface temperature and NDVI. *Geoscience and Remote Sensing, IEEE Transactions on* 48: 2509-2515.

Heitkamp, F., Maqsood, S., Sylvester, S., Kessler, M., and Jungkunst, H. 2015. Inacessible andean sites reveal land-use induced stabilisation of soil organic carbon. *EGU General Assembly Conference Abstracts*: 12228.

Herrick, J. E., Lessard, V. C., Spaeth, K. E., Shaver, P. L., Dayton, R. S., Pyke, D. A., Jolley, L., and Goebel, J. J. 2010. National ecosystem assessments supported by scientific and local knowledge. *Frontiers in Ecology and the Environment* 8: 403-408.

Hilker, T., Natsagdorj, E., Waring, R. H., Lyapustin, A., and Wang, Y. 2014. Satellite observed widespread decline in mongolian grasslands largely due to overgrazing. *Global change biology* 20: 418-428.

Holechek, J. L., Gomez, H., Molinar, F., and Galt, D. 1999. Grazing studies: What we've learned. Rangelands 21(2): 12-16.

Holm, A., Burnside, D., and Mitchell, A. 1987. The development of a system for monitoring trend in range condition in the arid shrublands of Western Australia. *The Rangeland Journal* 9: 14-20.

Holm, A. M., Bennett, L. T., Loneragan, W. A., and Adams, M. A. 2002. Relationships between empirical and nominal indices of landscape function in the arid shrubland of Western Australia. *Journal of Arid Environments* 50: 1-21.

Huete, A., and Jackson, R. 1988. Soil and atmosphere influences on the spectra of partial canopies. *Remote Sensing of Environment* 25: 89-105.

Huete, A., Jackson, R., and Post, D. 1985. Spectral response of a plant canopy with different soil backgrounds. *Remote sensing of environment* 17: 37-53.

Huete, A. R. 1988. A soil-adjusted vegetation index (savi). *Remote sensing of environment* 25: 295-309.

Hunt, J., E Raymond, Everitt, J. H., Ritchie, J. C., Moran, M. S., Booth, D. T., Anderson, G. L., Clark, P. E., and Seyfried, M. S. 2003. Applications and research using remote sensing for rangeland management. *Photogrammetric Engineering & Remote Sensing* 69: 675-693.

Ikeda, H., Okamoto, K., and Fukuhara, M. 1999. Estimation of aboveground grassland phytomass with a growth model using landsat tm and climate data. *International Journal of Remote Sensing* 20: 2283-2294.

Jackson, R. D., and Huete, A. R. 1991. Interpreting vegetation indices. *Preventive Veterinary Medicine* 11: 185-200.

Jafari, R., Lewis, M., and Ostendorf, B. 2007. Evaluation of vegetation indices for assessing vegetation cover in southern arid lands in south Australia. *The Rangeland Journal* 29: 39-49.

Jansen, V. S. 2014. Revealing livestock effects on bunchgrass vegetation with landsat ETM+ data across a grazing season, PhD thesis, University of Idaho.

Jauffret, S., Lavorel, S., and Leps, J. 2003. Are plant functional types relevant to describe degradation in arid, southern Tunisian steppes? *Journal of Vegetation Science* 14: 399-408.

Jenks, George F. 1967. "The Data Model Concept in Statistical Mapping", International Yearbook of Cartography 7: 186–190.

Jiang, Z., Huete, A. R., Chen, J., Chen, Y., Li, J., Yan, G., and Zhang, X. 2006. Analysis of ndvi and scaled difference vegetation index retrievals of vegetation fraction. *Remote sensing of environment* 101: 366-378.

Kairis, O., Karavitis, C., Salvati, L., Kounalaki, A., and Kosmas, K. 2015. Exploring the impact of overgrazing on soil erosion and land degradation in a dry Mediterranean agro-forest landscape (Crete, Greece). *Arid Land Research and Management* 29: 360-374.

Kakembo, V., Ndlela, S., and Cammeraat, E. 2012. Trends in vegetation patchiness loss and implications for landscape function: The case of pteronia incana invasion in the eastern cape province, South Africa. *Land Degradation & Development* 23: 548-556.

Kapalanga, T. S. 2008. A review of land degradation assessment methods. *Land Restoration Training Programme Keldnaholt* 112: 17-68.

Karnieli, A., Bayarjargal, Y., Bayasgalan, M., Mandakh, B., Dugarjav, C., Burgheimer, J., Khudulmur, S., Bazha, S., and Gunin, P. 2013. Do vegetation indices provide a reliable indication of vegetation degradation? A case study in the Mongolian pastures. *International journal of remote sensing* 34: 6243-6262.

Kawamura, K., Akiyama, T., Yokota, H.-o., Tsutsumi, M., Yasuda, T., Watanabe, O., and Wang, S. 2005. Quantifying grazing intensities using geographic information systems and satellite remote sensing in the xilingol steppe region, inner Mongolia, China. *Agriculture, ecosystems & environment* 107: 83-93.

Kong, T. M., Marsh, S. E., van Rooyen, A. F., Kellner, K., and Orr, B. J. 2015. Assessing rangeland condition in the Kalahari duneveld through local ecological knowledge of livestock farmers and remotely sensed data. *Journal of Arid Environments* 113: 77-86.

Koohafkan, P., Lantieri, D., and Nachtergaele, F. 2003. Land degradation assessment in drylands (lada): Guidelines for a methodological approach. Land and water development division, FAO, Rome.

Koyama, A., Yoshihara, Y., Jamsran, U., and Okuro, T. 2015. Role of tussock morphology in providing protection from grazing for neighbouring palatable plants in a semi-arid Mongolian rangeland. *Plant Ecology & Diversity* 8: 163-171.

Kwok, A. B., Eldridge, D. J., and Oliver, I. 2011. Do landscape health indices reflect arthropod biodiversity status in the eucalypt woodlands of Eastern Australia? *Austral Ecology* 36: 800-813.

Lantierei, D., and Young, A. 2003. Potential use of satellite remote sensing for land degradation assessment in drylands: Application to the lada project. Environment and Natural Resources Service, Sustainable Development Department, Rome: FAO.

Lau, I., Hewson, R., Ong, C., and Tongway, D. 2008. Remote minesite rehabilitation monitoring using airborne hyperspectral imaging and landscape function analysis (lfa). *Int. Arch. Photogramm. Remote. Sens. Spat. Inf. Sci* 37: 325-330.

Le Houerou, H. N. 1977. Man and desertization in the mediterranean region. Ambio 6: 363-365.

Le Houerou, H. N. 2000. Restoration and rehabilitation of arid and semiarid mediterranean ecosystems in north africa and west Asia: A review. *Arid Soil Research and Rehabilitation* 14: 3-14.

Le Houérou, H. N. 2001. Biogeography of the arid steppeland north of the Sahara. *Journal of Arid Environments* 48: 103-128.

Lezama, F., Baeza, S., Altesor, A., Cesa, A., Chaneton, E. J., and Paruelo, J. M. 2014. Variation of grazing-induced vegetation changes across a large-scale productivity gradient. *Journal of Vegetation Science* 25: 8-21.

Li, J., Okin, G. S., Alvarez, L., and Epstein, H. 2007. Quantitative effects of vegetation cover on wind erosion and soil nutrient loss in a desert grassland of southern New Mexico, USA. *Biogeochemistry* 85: 317-332.

Lind, M., Rasmussen, K., Adriansen, H., and Ka, A. 2003. Estimating vegetative productivity gradients around watering points in the rangelands of northern senegal based on noaa avhrr data. *Geografisk Tidsskrift-Danish Journal of Geography* 103: 1-15.

Liu, A., Wang, J., Liu, Z., and Wang, J., Monitoring desertification in arid and semi-arid areas of China with NOAA-AVHRR and MODIS data, In proceeding of Geoscience and Remote Sensing Symposium, IEEE International: Beijing. 2005.

López-Poma, R., Mayor, Á. G., and Bautista, S., Using soil functional indices to assess wildfire impact. In proceeding of EGU General Assembly Conference , Vienna, Austria, April 27- May 2, 2014. EGU General Assembly.2014.

López, D. R., Brizuela, M. A., Willems, P., Aguiar, M. R., Siffredi, G., and Bran, D. 2013. Linking ecosystem resistance, resilience, and stability in steppes of north Patagonia. *Ecological Indicators* 24: 1-11.

Louhaichi, M., and Johnson, D. E. Rangeland management policy in western north africa. The 2008 Joint Meeting of the Society for Range Management and the America Forage and Grassland Council.

Lu, X., Yan, Y., Sun, J., Zhang, X., Chen, Y., Wang, X., and Cheng, G. 2015. Short-term grazing exclusion has no impact on soil properties and nutrients of degraded alpine grassland in Tibet, China. Solid Earth.

Luan, J., Cui, L., Xiang, C., Wu, J., Song, H., Ma, Q., and Hu, Z. 2014. Different grazing removal exclosures effects on soil c stocks among alpine ecosystems in east Qinghai–Tibet plateau. *Ecological Engineering* 64: 262-268.

Ludwig, F., de Kroon, H., Berendse, F., and Prins, H. H. 2004. The influence of savanna trees on nutrient, water and light availability and the understorey vegetation. *Plant Ecology* 170: 93-105.

Ludwig, J., Tongway, D., Hodgkinson, K., Freudenberger, D., and Noble, J. 1996. Landscape ecology, function and management: Principles from Australia's rangelands, pp. 20-33 Canberra: CSIRO.

Ludwig, J. A., and Tongway, D. J. 1995. Spatial organisation of landscapes and its function in semi-arid woodlands, Australia. *Landscape Ecology* 10: 51-63.

Ludwig, J. A., Wilcox, B. P., Breshears, D. D., Tongway, D. J., and Imeson, A. C. 2005. Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes. *Ecology* 86: 288-297.

Lund, H. G. 2007. Accounting for the world's rangelands. *Rangelands*, 29: 3-10.

Maestre, F. T., and Cortina, J. 2006. Ecosystem structure and soil-surface conditions drive the variability in the foliar δ13c and δ15n of Stipa Tenacissima in semiarid Mediterranean steppes. *Ecological Research* 21: 44-53.

Maestre, F. T., and Escudero, A. 2009. Is the patch size distribution of vegetation a suitable indicator of desertification processes? *Ecology* 90: 1729-1735.

Maestre, F. T., and Puche, M. D. 2009. Indices based on surface indicators predict soil functioning in Mediterranean semi-arid steppes. *Applied soil ecology* 41: 342-350.

Maestre, F. T., Quero, J. L., Gotelli, N. J., Escudero, A., Ochoa, V., Delgado-Baquerizo, M., García-Gómez, M., Bowker, M. A., Soliveres, S., and Escolar, C. 2012. Plant species richness and ecosystem multifunctionality in global drylands. *Science* 335(6065): 214-218.

Mahmoud, A., Gadallah, A., Mohemmed, S., Mohamed, M., Abdel-Ghani, A., Alhendawi, R., and Russell, P. J., Aspects of range condition recovery in the southern Al-Jebel Al-Akhdar, northeastern Libya, In Proceedings of the International Rangeland Congress, Hohhot, China.2008

Mahmoud, A. M., Alhendawi, R. A., and Russell, P. J., The Effect of Average Rainfall on Recovery of Arid Shrubland in southern Al-Jebel Al-Akhdar, northeastern Libya, In Proceedings of the First International Conference on Water Resources in Al-Jebel Al-Akhdar, El-Bayda, Libya. University of Omar Almukhtar.2012.

Marsett, R. C., Qi, J., Heilman, P., Biedenbender, S. H., Watson, M. C., Amer, S., Weltz, M., Goodrich, D., and Marsett, R. 2006. Remote sensing for grassland management in the arid southwest. *Rangeland Ecology & Management* 59: 530-540.

Masson, L. F., McNeill, G., Tomany, J. O., Simpson, J. A., Peace, H. S., Wei, L., ... and Bolton-Smith, C. 2003. Statistical approaches for assessing the relative validity of a food-frequency questionnaire: use of correlation coefficients and the kappa statistic. Public health nutrition 6: 313-321.

Mayor, Á. G., and Bautista, S. 2012. Multi-scale evaluation of soil functional indicators for the assessment of water and soil retention in mediterranean semiarid landscapes. *Ecological Indicators* 20: 332-336.

Mazzarino, M., Bertiller, M., Sain, C., Laos, F., and Coronato, F. 1996. Spatial patterns of nitrogen availability, mineralization, and immobilization in northern Patagonia, Argentina. *Arid Land Research and Management* 10: 295-309.

McDonagh, J., Bunning, S., McGarry, D., Liniger, H., Rioux, J., Biancalani, R., and Nachtergaele, F. 2009. Field manual for local level land degradation assessment in drylands. LADA, FAO. Rome.

McIntyre, B. S., and Tongway, D. 2005. Grassland structure in native pastures: links to soil surface condition. Ecological Management and Restoration 6: 43-50.

Middleton, N., and Thomas, D. 1997. World atlas of desertification, Arnold, Hodder Headline, PLC.

Milton, S. J., Dean, W. R. J., du Plessis, M. A., and Siegfried, W. R. 1994. A conceptual model of arid rangeland degradation. BioScience 44: 70-76.

Mirreh, M. M., and Diranai, M. S. 2014. Effect of protection and grazing pressure on the desert rangelands of Al Jouf region, Saudi Arabia. Range Management In Arid Zones: 189.

Mróz, M., and Sobieraj, A. 2004. Comparison of several vegetation indices calculated on the basis of a seasonal spot xs time series, and their suitability for land cover and agricultural crop identification. *Technical Sciences* 7: 39-66.

Muñoz-Robles, C., Frazier, P., Tighe, M., Reid, N., Briggs, S. V., and Wilson, B. 2012. Assessing ground cover at patch and hillslope scale in semi-arid woody vegetation and pasture using fused quickbird data. *International Journal of Applied Earth Observation and Geoinformation* 14: 94-102.

Muñoz-Robles, C., Reid, N., Tighe, M., Briggs, S. V., and Wilson, B. 2011. Soil hydrological and erosional responses in patches and inter-patches in vegetation states in semi-arid Australia. *Geoderma* 160: 524-534.

Munro, N. T., Fischer, J., Wood, J., and Lindenmayer, D. B. 2012. Assessing ecosystem function of restoration plantings in south-eastern Australia. *Forest Ecology and Management* 282: 36-45.

Najeeb, A. A. 2009. Estimation of the normalized difference vegetation index (ndvi) variation for selected regions in Iraq for two years. *Journal of University of Anbar for pure science* 3: 1991- 8941.

Nicholson, S. E., Davenport, M. L., and Malo, A. R. 1990. A comparison of the vegetation response to rainfall in the sahel and east africa, using normalized difference vegetation index from noaa avhrr. *Climatic Change* 17: 209-241.

Numata, I., Roberts, D. A., Chadwick, O. A., Schimel, J., Sampaio, F. R., Leonidas, F. C., and Soares, J. V. 2007. Characterization of pasture biophysical properties and the impact of grazing intensity using remotely sensed data. *Remote Sensing of Environment* 109: 314-327.

Oldeman, L. R., Soil degradation: A threat to food security. International Soil Refernce and Information Centre. ISRIC: Wageningen. 1998.

Oñatibia, G. R., Aguiar, M. R., and Semmartin, M. 2015. Are there any trade-offs between forage provision and the ecosystem service of c and n storage in arid rangelands? *Ecological Engineering* 77: 26-32.

Ong, C., Tongway, D., Caccetta, M., and Hindley, N., Deriving ecosystem function analysis indices from airborne hyperspectral data. CSIRO: Camberra. 2009.

Owusu, A. B. 2013. Detecting and quantifying desertification in the upper east region of ghana using multi-spatial and multi-temporal normalized difference vegetation index. *Journal of Environment and Earth Science* 3: 62-78.

Papanastasis, V. P., Bautista, S., Chouvardas, D., Mantzanas, K., Papadimitriou, M., Mayor, A. G., Koukioumi, P., Papaioannou, A., and Vallejo, R. V. 2015. Comparative assessment of goods and services provided by grazing regulation and reforestation in degraded mediterranean rangelands. Land Degradation and Development DOI: 10.1002/ldr.2368.

Paredes, P. 2011. Caracterización funcional de la estepa magallánica y su transición a matorral de mata negra (patagonia austral) a partir de imágenes de resolución espacial intermedia. Magister thesis. Universidad de Buenos Aires.

Parker, D., Bernard, R., and Adendorff, J. 2009. Do elephants influence the organisation and function of a South African grassland? *The Rangeland Journal* 31: 395-403.

Paudel, K. P., and Andersen, P. 2010. Assessing rangeland degradation using multi temporal satellite images and grazing pressure surface model in upper mustang, Trans Himalaya, Nepal. *Remote Sensing of Environment* 114: 1845-1855.

Perry, C. R., and Lautenschlager, L. F. 1984. Functional equivalence of spectral vegetation indices. *Remote sensing of environment* 14: 169-182.

Phillips, R., Beeri, O., Scholljegerdes, E., Bjergaard, D., and Hendrickson, J. 2009. Integration of geospatial and cattle nutrition information to estimate paddock grazing capacity in northern US prairie. *Agricultural systems* 100: 72-79.

Ponce-Hernandez, R. 2002. Land degradation assessment in drylands: Approach and development of a methodological framework. Rome: AGLL, FAO.

Ponce-Hernandez, R., and Koohafkan, P. 2010. A methodology for land degradation assessment at multiple scales based on the dpsir approach: Experiences from applications to drylands. Land degradation and desertification: Assessment, mitigation and remediation, pp 49-65. Trent University.

Qi, J., Chehbouni, A., Huete, A., Kerr, Y., and Sorooshian, S. 1994. A modified soil adjusted vegetation index. *Remote sensing of environment* 48: 119-126.

Raiesi, F., and Riahi, M. 2014. The influence of grazing exclosure on soil c stocks and dynamics, and ecological indicators in upland arid and semi-arid rangelands. *Ecological Indicators* 41: 145-154.

Richardson, A. J., and Weigand, C. 1977. Distinguishing vegetation from soil background information. Photogrammetric Engineering and Remote Sensing 43: 1541-1552.

Rivero, R., Grunwald, S., Binford, M., and Osborne, T. 2009. Integrating spectral indices into prediction models of soil phosphorus in a subtropical wetland. *Remote Sensing of Environment* 113: 2389-2402.

Rondeaux, G., Steven, M., and Baret, F. 1996. Optimization of soil-adjusted vegetation indices. *Remote sensing of environment* 55: 95-107.

Rong, Y., Yuan, F., and Ma, L. 2014. Effectiveness of exclosures for restoring soils and vegetation degraded by overgrazing in the Junggar basin, China. Grassland Science 60: 118-124.

Rouse Jr, J., Haas, R., Schell, J., and Deering, D. 1974. Monitoring vegetation systems in the great plains with erts, pp. 309. Washington, D.C: NASA.

Russell, P. J. 2006. Project Proposal for MSc Students. Faculty of Natural Resources and Environmental Sciences, University of Omar Almukhtar, Centere of the Management of Arid Environments, and Curtin University of Technology.

Russell, P. J. 2007. Assessing long-term change in rangeland ecological health using the western australian rangeland monitoring system, PhD Thesis, Curtin University of Technology.

Sandhage-Hofmann, A., Kotzé, E., van Delden, L., Dominiak, M., Fouché, H., van der Westhuizen, H., Oomen, R., du Preez, C., and Amelung, W. 2015. Rangeland management effects on soil properties in the savanna biome, South Africa: A case study along grazing gradients in communal and commercial farms. *Journal of Arid Environments* 120: 14-25.

Sanosi, M. 2008. Estimation of carrying capacity in south Al-Jabal Alakhdar rangelands, Master thesis (in arabic), Faculty of Natural Resources and Environmental Sciences, University of Omar Al- Mukhtar.

Schlesinger, W. H., Reynolds, J., Cunningham, G. L., Huenneke, L., Jarrell, W., Virginia, R., and Whitford, W. 1990. Biological feedbacks in global desertification. *Science* 247: 1043-1048.

Semple, W., Cole, I., Koen, T., Costello, D., and Stringer, D. 2006. Native couch grasses for revegetating severely salinised sites on the inland slopes of nsw. Part 2. *The Rangeland Journal* 28: 163-173.

Senseman, G. M., Tweddale, S. A., Anderson, A. B., and Bagley, C. F., Correlation of land condition trend analysis (LCTA) rangeland cover measures to satellite-imagery-derived vegetation indices. US Army Corps of Engineers: Washington, D.C . 1996.

Sholihah, A., and Sjarmidi, A. 2014. Ecosystem evaluation of post sand mining land in cimalaka, sumedang. *Journal of Degraded and Mining Lands Management* 1: 75-78.

Siroosi, H., Heshmati, G. A., Mahini, A. S., and Naseri, H. R. 2012. An assessment of structural characteristics of patches in different natural and managerial conditions in taleghan (case study: Karkaboud and kouin). *World Applied Sciences Journal* 17: 631-636.

Snyman, H., and Du Preez, C. 2005. Rangeland degradation in a semi-arid South Africa. Influence on soil quality. *Journal of arid environments* 60: 483-507.

Soliveres, S., and Eldridge, D. J. 2014. Do changes in grazing pressure and the degree of shrub encroachment alter the effects of individual shrubs on understorey plant communities and soil function? *Functional ecology* 28: 530-537.

Su, X., Dong, S., Liu, S., Wu, Y., Zhao, H., Zhang, X., Weng, J., Tang, L., Wu, X., and Hou, P. 2015. Changes in rangeland cover associated with livestock grazing in altun national nature reserve, northwest Qinghai-Tibetan plateau. *The Rangeland Journal* 37: 97-105.

Svoray, T., Perevolotsky, A., and Atkinson, P. M. 2013. Ecological sustainability in rangelands: The contribution of remote sensing. *International Journal of Remote Sensing* 34: 6216-6242.

SWECO. 1986. Land survey, mapping and pasture survey for 550,000 hectares of south Al-Jebel Al-Akhdar area. University of Omar Al- Mukhtar: Elbaida.

Talore, D., Tesfamariam, E. H., Hassen, A., Du Toit, J., Klumpp, K., and Soussana, J. 2015. Long-term impacts of season of grazing on soil carbon sequestration and selected soil properties in the arid eastern cape, South Africa. Plant and Soil 397: 317-329

Thompson, W. A., Eldridge, D. J., and Bonser, S. P. 2006. Structure of biological soil crust communities in callitris glaucophylla woodlands of New South Wales, Australia. *Journal of Vegetation Science* 17: 271-280.

Tongway, D. 1995.Monitoring soil productive potential. Desertification in developed countries, pp. 303-318. Canberra: CSIRO.

Tongway, D., and Hindley, N. 2004. Landscape function analysis: A system for monitoring rangeland function. *African journal of range and forage science* 21: 109-113.

Tongway, D. J., Rangeland soil condition assessment manual. CSIRO: Canberra. 1994.

Tongway, D. J. 2010. Teaching the assessment of landscape function in the field: Enabling the design and selection of appropriate restoration techniques. *Ecological Restoration* 28: 182-187.

Tongway, D. J., and Ludwig, J. A. 2007. Restoring Natural Capital: Science, Business, and Practice, pp. 76-84. Washington: Island Press.

Tongway, D. J., and Ludwig, J. A. 2011. Restoring disturbed landscapes: Putting principles into practice, pp. 145-151. Washington: Island Press.

Tsalyuk, M., Kelly, M., Koy, K., Getz, W. M., and Butterfield, H. S. 2015. Monitoring the impact of grazing on rangeland conservation easements using modis vegetation indices. *Rangeland Ecology & Management* 68: 173-185.

Tucker, C. J. 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote sensing of Environment 82: 127-150.

Van der Walt, L., Cilliers, S., Kellner, K., Tongway, D., and Van Rensburg, L. 2012. Landscape functionality of plant communities in the impala platinum mining area, rustenburg. *Journal of environmental management* 113: 103-116.

Van Leeuwen, W. J. D., and Huete, A. R. 1996. Effects of standing litter on the biophysical interpretation of plant canopies with spectral indices. Remote Sensing of Environment, 55: 123-138.

Van Oudenhoven, A. P., Veerkamp, C. J., Alkemade, R., and Leemans, R. 2015. Effects of different management regimes on soil erosion and surface runoff in semi-arid to sub-humid rangelands. *Journal of Arid Environments* 121: 100-111.

Vásquez-Méndez, R., Ventura-Ramos, E., Oleschko, K., Hernández-Sandoval, L., Parrot, J.-F., and Nearing, M. A. 2010. Soil erosion and runoff in different vegetation patches from semiarid central Mexico. *Catena* 80: 162-169.

Vescovo, L., and Gianelle, D. 2008. Using the mir bands in vegetation indices for the estimation of grassland biophysical parameters from satellite remote sensing in the alps region of Trentino (Italy). *Advances in space research* 41: 1764-1772.

Walther, D., and Shabaani, S. 1991. Large scale monitoring of rangelands vegetation using NOAA/avhrr lac data: Application to the rainy seasons 1989/90 in northern kenya, pp. 3- 4. Nairobi: Ministry of Livestock Development.

Wang, J., Yan, Q., Liu, Z., and Luo, C. 2013. Analysis on the change of vegetation coverage in qinghai province from 2000 to 2012. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 1: 121-126.

Wang, Q., and Batkhishig, O. 2014. Impact of overgrazing on semiarid ecosystem soil properties: A case study of the eastern hovsgol lake area, Mongolia. *Journal of Ecosystem and Ecography* 4:140-147.

Washington-Allen, R. A., West, N. E., Ramsey, R. D., and Efroymson, R. A. 2006. A protocol for retrospective remote sensing-based ecological monitoring of rangelands. *Rangeland Ecology and Management* 59: 19-29.

Watson, I., Thomas, P., and Fletcher, W. 2007. The first assessment, using a rangeland monitoring system, of change in shrub and tree populations across the arid shrublands of Western Australia. *The Rangeland Journal* 29: 25-37.

Weiss, E., Marsh, S., and Pfirman, E. 2001. Application of noaa-avhrr ndvi time-series data to assess changes in Saudi Arabia's rangelands. *International Journal of Remote Sensing* 22: 1005-1027.

West, N. E. 2003. History of rangeland monitoring in the USA. *Arid Land Research and Management* 17: 495-545.

Wilcoxon, F. 1945. Individual comparisons by ranking methods. Biometrics bulletin, 1: 80-83.

Yacouba, D., Guangdao, H., and Xingping, W. 2009. Assessment of land use cover changes using ndvi and dem in puer and simao counties, yunnan province, China. *World Rural Observations* 1: 1-11.

Yang, X., and Guo, X. 2011. Investigating vegetation biophysical and spectral parameters for detecting light to moderate grazing effects: A case study in mixed grass prairie. *Central European Journal of Geosciences* 3: 336-348.

Yari, R., TAVILI, A., and ZARE, S. 2012. Investigation on soil surface indicators and rangeland functional attributes by landscape function analysis (lfa)(case study: Sarchah Amari Birjand). Iranian Journal of Range and Desert Research 18: 624-636.

Yates, C. J., Norton, D. A., and Hobbs, R. J. 2000. Grazing effects on plant cover, soil and microclimate in fragmented woodlands in south-Western Australia: Implications for restoration. *Austral Ecology* 25: 36-47.

Yeganeh, H., jamale Khajedein, S., Amiri, F., and Shariff, A. R. B. M. 2014. Monitoring rangeland ground cover vegetation using multitemporal modis data. *Arabian Journal of Geosciences* 7: 287-298.

Zatout, M. M. 2014. Effect of negative human activities on plant diversity in the Jabal Akhdar pastures. *International Journal of Bioassays* 3: 3324-3328.

Zhang, Y., and Chen, X. 2014. Spatiotemporal dynamics of normalized difference vegetation index in China based on remote sensing images. Mechatronics and automatic control systems, pp. 1003-1009. Switzerland: Springer.

Zhang, Y., Gao, Q., Dong, S., Liu, S., Wang, X., Su, X., Li, Y., Tang, L., Wu, X., and Zhao, H. 2015. Effects of grazing and climate warming on plant diversity, productivity and living state in the alpine rangelands and cultivated grasslands of the Qinghai-Tibetan plateau. *The Rangeland Journal* 37: 57-65.

Zhang†, C., and Guo, X. 2008. Monitoring northern mixed prairie health using broadband satellite imagery. *International Journal of Remote Sensing* 29: 2257-2271.

Zhao, B., Yan, Y., Guo, H., He, M., Gu, Y., and Li, B. 2009. Monitoring rapid vegetation succession in estuarine wetland using time series modis-based indicators: An application in the Yangtze river delta area. *Ecological Indicators* 9: 346-356.

Zucca, C., Arrieta Garcia, S., Deroma, M., and Madrau, S. 2015a. Organic carbon and alkalinity increase in topsoil after rangeland restoration through atriplex nummularia plantation. Land Degradation and Development 27: 573-582

Zucca, C., Pulido-Fernández, M., Fava, F., Dessena, L., and Mulas, M. 2013. Effects of restoration actions on soil and landscape functions: A*triplex nummularia* Plantations in ouled dlim (central Morocco). *Soil and Tillage Research* 133: 101-110.