# ABSTRACT

This research is an attempt to use remote sensing and GIS techniques together with field survey to investigate and acquire knowledge about status of the forest cover of ed Dallinjand Nabag forests and how to use that in managing forest in sustainable basis. And further estimate the vegetation change trends and dynamics during the period 1985-2007. The study used a multi-temporal satellite imagery of ASTER L1b 2007, Landsat TM 1997, TM 1987 and TM 1985. The study was supported by a field inventory through which data were collected and used for, imagery registration, classification processes, and structure of the correlations and discussion of the results. ERDAS Imagine, ARC/GIS, SPSS and Microsoft Excel software were been used for image processing and data analysis.

Initially, the images were been primary processed, calibrated and reprojcted to the UTM zone 35, Spheroid and Datum WGS 84. Then they have been classified unsupervisedly for spectral analysis and design of the field sampling frame. Stratified random sampling design was framed for the field survey. The field data was collected through direct measurements, interviews with key persons and observation. Afterwards, supervised classification has been applied to the study imagery and forest and vegetation cover maps were produced. The classified images were then used to produce the change detection maps and indices of change dynamics. Besides that NDVI and vegetation change matrices were used for accuracy assessment and verification. Concerning the field data, mathematical models and equation have been developed to estimate the tree height, diameter and volume.

Concerning Ed Dillinj, the study area and its surrounding was initially classified in to four land use land cover classes namely; Forest land, Bare land, Rocks + Basement complex and Residential area. Then after the reserved forest was classified into two classes: forest land and bare land. The primary classification showed that the forest cover area has decreased from 1271.8 ha in 1987 to only 561.ha and 458.4 ha in 1997 and 2007 respectively. In the same time the bare land area has increased from 905.7 ha in 1987 to 1161.4 ha in 1997 and 1300.4 ha in 2007. Concerning the forest reservation it has been found that the forest area was 106.6 ha, 102.6 ha and 85.8 ha in 1987, 1997 and 2007 respectively. For the same period the bare land area was about 49 ha in 1987 and increased to 54.3 ha in 1997 and 67 ha in 2007. In refer to the reserved forest, the NDVI area calculated showed a great decrease between the period 1987/2007. Moreover, the change detection and matrices results had also showed a significant change of the forest cover between 1987-1997 and less ones for the period 1997-2007.

Concerning Nabag forest it has been classified into forest, shrubs + range land and bare land categories. The results indicated that the forest land area dominated by *Hashab* trees was 699.5 ha in 1985 and decreased to 434.2 ha in 1997 and 659.9 ha in 2007. For the same period the bare land area was increased from 1046.9 ha in 1985 to 1398.1 ha in 1997, but decreased by about 10% in 2007. In the other hand the shrubs and range land category has decreased from 562.6 ha in 1985 to 476.7 ha in 1997, while it was increased to nearly the third in 2007. The results also showed that the forest category NDVI has decreased by more than the third between 1985 and 1997.The negative NDVI value that represents bare land and other non-vegetated materials has showed increased from 1017.6 ha in 1985 to

1553.5 ha in 1997. The change detection assessment results showed that Nabag forest cover was changed greatly between the period 1985, 1997 and 2007.

In refer to the field survey analysis; mathematical models and functions were been structured for estimation of mean height and volume of the forest cover in the study area from the NDVI. For ed Dallinjforest the average number of trees per hectare was more than 118 trees and the average volume per hectare was estimated by 22.42 $m^3$. Concerning Nabag forest the average number of trees per hectare was the same however, the average volume per hectare was too small (3.7 $m^3$).

The study concluded that the forest cover of ed Dallinjand Nabag forests cover has changed greatly during the period 1985/1997 while the period 1997 to 2007 showed small change. Also, the study investigated that the use of medium multi-temporal satellite imagery for assessment and mapping forest cover change trend and dynamics in the arid land could give optimal results when the vegetation cover has high chlorophyll contents. Therefore, the study recommended using high resolution satellite imagery in such cases.

# خلاصة

هذه الدراسة عبارة عن محاولة لاستخدام تقنيات الاستشعار عن بعد و نظم المعلومات الجغرافية مصحوبة بالمسح الحقلي لدراسة و استخلاص معلومات عن الحالة الراهنة لغابتي الدلنج و نبق بجنوب كردفان و مدى الاستفادة منها في الادارة المستدامة للغابات. بالاضافة الى ذلك معرفة و تقييم اتجاه و ديناميكية التغير في الغطاء النباتي و الغابوي للفترة من 1985م الى 2007م. استخدمت الدراسة لذلك صور أقمار صناعية للاندسات (Landsat) و أستر (ASTER) متوسطة التمييز المكاني للأعوام 1985م،1987م، 1997م و 2007م. دعمت الدرلسة بمسح ميداني تم من خلاله جمع معلومات استخدمت في تصحيح صور الأقمار الصناعية، عمليات التصنيف، انشاء العلاقات الارتباطية و مناقشة النتائج.

في البدأ تم تصحيح الصور و اعادة توجيهها للنظام العالمي للاحداثيات (UTM) المجال 35 و المسح الجيولوجي للعالم 84 (WGS 84). ثم من بعد تم تصنيف الصور تصنيفاُ غير مراقباً لاجراء الاختبارات الطيفية و تصميم نظام العينة الحقلية. تم اختيار النظام الطبقي ذات العينة العشوائية لجمع المعلومات الحقلية. تم جمع المعلومات الحقلية عن طريق المسح المباشر, المقابلات مع المسؤليين و الملاحظة. و من بعدها تم تصنيف صور الاقمار الصناعية تصنيفاً غير مراقب وانتاج الخرائط و المعلومات الخاصة بالغطاء النباتي و الغابي و ديناميكية التغير. مع ذلك تم استخدام مؤشر الفرق في الغطاء النباتي (NDVI) و متطابقات التغير في الغطاء النباتي لتقييم صحة المعلومات و تحقيقها. بخصوص المعلومات الحقلية بعضها تم حسابها مباشرةً و البعض الاخر أستخلصت بعد تطوير بعض النماذج و المعادلات الرياضية. تم كل ذلك باستخدام برامج ERDAS Imagine 9.1, ARCGIS 9.2, SPSS and Excel.

بالنسبة للدلنج في البدأ تم تصنيف و دراسة الغطاء النباتي و الغابوي و استخدامات الأرض لغابة الدلنج المحجوزة و المنطقة ما حولها. بناءاً علي ذلك تم تقسيمها الى أربعة أقسام هي: غابات, أرض جرداء, منطقة صخور و أحجار و منطقة سكنية. في المرحلة التالية تم تقسيم غابة الدلنج المخحوزة الى قسمين هما: منطقة غابات و أرض جرداء. نتائج التصنيف أظهرت أن الغطاء الغابوي العام لمنطقة الدلنج قد تقلصت من 1271 هيكتار في العام 1987م الى 561 هيكتار و 458 هيكتار للأعوام 1997م و 2007م على التوالي. في الوقت نفسه ذادت مساحة الأرض الجرداء من 905 هيكتار في العام 1987م الى 1300.4 هيكتار في العام 2007. بالنسبة لغابة الدلنج المحجوزة أظهرت النتائج أن مساحة الغابة قد تقلصت من 106 هيكتار في العام 1987م

الى 85 هيكتار في العام 2007م. لتأكيد ذلك فان نتائج تحليل مؤشر الفرق العام للغطاء النباتي قد أظهر ذات التقلص في الغطاء النباتي بين العام 1987م و 2007م.

بالنسبة لغابة نبق فان نتائج الدراسة أشارة الى تقلص مساحة الغابة من 699 هيكتار في العام 1985م الى 434 هيكتار و 659 هيكتار للأعوام 1997م و 2007م على التوالي. و كان ذلك مصحوباً بزيادة في مساحة الأرض الجرداء من 1046 هيكتار في العام 1985م الى 1398.1 هيكتار في العام 1997م. تأكيداً لذلك فان مؤشر الفرق في الغطاء النباتي أظهر تقلص في المساحة التي تمثل الغطاء الغابي الى أكثر من الثلث في الفترة 1985م الى 2007م, في الوقت ذاته أشار الى زيادة المساحة التي تمثل الأرض الجرداء من 1017 هيكتار في العام 1985م الى 1553 هيكتار في العام 1997م.

بخصوص المسح الميداني فقد تم تطوير علاقات و نماذج رياضية لحساب ارتفاع الأشجار و حجم الأخشاب. بالنسبة لغابة الدلنج أظهرت نتائج التحليل أن متوسط عدد الأشجار في الهيكتار تساوي 118 شجرة, بينما بلغ متوسط انتاج الخشب للهيكتار 22.42 م$^3$ . بالاشارة الى غابة نبق فان مساحتها كانت كبيرة نسبياً لذلك تطوير معادلات و نماذج رياضية لتقدير ارتفاعات الأشجار و الحجوم بالنسبة لشجرة الهشاب السائدة في الغابة . بناءاً عليه فقد تم تقدير متوسط عدد الأشجار في الهيكتار بما يساوي 118 شجرة, بينما بلغ متوسط انتاج الخشب للهيكتار 3.7 م$^3$. بالاضافة الى ذلك فقد تم تطوير علاقة لتقدير حجم الخشب لأشجار الهشاب من مؤشر الفرق للغطاء النباتي.

خلصت الدراسة الى وجود تغير في الغطاء النباتي و الغابوي للدلنج و نبق و كان ذلك بصورة كبيرة للفترة 1985م الى 1997م و أقل للحقبة 1997م الى 2007م. من جهة أخرى فقد أظهرت الدراسة أن استخدام صور الأقمار الصناعية ذات التمييز المكاني المتوسط في دراسة التغير النباتي و الغابوي في المناطق الجافة تعطي نتائج جيدة في حالة النباتات التي تحتوي على نسبة عالية من الكلوروفيل, بينما تكون النتائج ضعيفة عكس ذلك. عليه توصي الدراسة باستخدام صور الأقمار الصناعية ذات التمييز المكاني العالي في مثل هذه الحالات.

# ACKNOWLEDGMENT

"*Every editor and compiler whatever the nature of the book on which he is working inevitably consults his friends and associates (Milton, 2005)*".

The completion of this thesis could not be possible without the vital support from Professor Dr. Elmar Csaplovics from TU Dresden Germany who's not only served as main supervisor but also encouraged and challenged me throughout my academic program. With a deep sense of gratitude, I wish to express my sincere thanks to him and his staff.

I would like to acknowledge and extend my heartfelt gratitude to the co-supervisors Prof. Dr. Abdelhafeez Ali Mohamed and Dr. El-Abbas Doka M. whom guided me throughout the dissertation process.

I would like send my grateful acknowledgment to German Academic Exchange Service (DAAD) for the financial support of this research.

It is a pleasure to express my gratitude wholeheartedly to Dr. Ismail M. Fangama for the help and inspiration he extended to me and my family.

Collective and individual acknowledgments are also owed to my colleagues at College of Forestry and Range Science and Sudan University of Science and Technology.

I would like to extend my thanks to ed Dallinjforest department and Ed Dibaibat forest rangers and workers for their assistant during the field work.

I wish to thank MSc Mohammed Hamid for the support in statistical analysis and formulation of the models and equations.

I wish to thank all my colleagues at TU Dresden for their cooperation and assistance.

I would like to thank Mr. Roger McCoy who offered me the book of "Field Methods in Remote Sensing" which assisted me much in the field work.

I would to express my thanks to Mr. Gerd Wuesteney for his assistance and encouragement during my research.

Special thanks to the Sudan Remote Sensing Authority for the provision of data and support.

Where would I be without my family? I am grateful to my wife Bashra for the inspiration and moral support she provided throughout my research work and her patience and take care for our children. Without her loving support and understanding I would never have completed my present work. Particularly, I owe to my sons Algazooly and Albahi whom lost me so much during my research. I also deeply thanks sister-in-law Hikma for her much support to my family.

I am very glad and owed to share this moment of happiness with my father and mother, brothers, sisters and the great family whom rendered me enormous support during the whole tenure of my research and academy.

Finally, I would like to thank all whose direct and indirect support or helped me completing my thesis, as well as expressing my apology for that I could not mention personally.

*Sincerely Yours*

*Mahgoub*

# Dedication

I dedicate this thesis to my wife and sons, my parents, brothers and sisters; and to the spirit of my brother Imam who was lost due to Darfur crises.

# Table of Contents

# List of Tables

# List of Figures

# List of Abbreviations and Acronyms

**AOI:** Area of Interest

**APM:** Automatic Point Measurement

**ASTER:** Advanced Space-borne Thermal Emission and Reflection Radiometer

**B:** Blue

**CCFM:** Canadian Council of Forest Ministers

**CRS:** Creative Research Systems

**DBH:** Diameter at Breast Height

**DRC:** Diameter at Root Collar

**EOS:** Earth Observation System

**Equ.:** Equation

**ERSDAC:** Japan's Earth Remote Sensing Data Analysis Center

**ETM:** Enhanced Thematic Mapper

**FAO:** Food and Agriculture Organization of the United Nation

**FF:** Form Factor

**FFS:** Fast Facts of Sudan

**FNC:** Sudan Forest National Corporation

**FPCS:** Forests Products Consumption Survey

**FRA:** Forest Resources Assessment of FAO

**G:** Green

**GCP:** Ground Control Point

**GDP:** Gross Domestic Products

**GIS:** Geographical Information System

**GPS:** Geographical Positioning System

**H:** Height

**ha:** hectare

**LULC:** Land Use Land Cover

**NASA:** National Aeronautics and Space Administration

**NDVI:** Normalized Difference Vegetation Index

**NFRI:** National Forest Resource Inventory

**NIR:** Near Infrared

**PCA:** Principal Component Analysis

**R:** Red

**SFM:** Sustainable Forest Management

**SKRDP &NSKRDP:** South Kordofan Range Management Strategy Study & Khor Abu Habil Basin Planning and Water Development

**SRAAD:** Sudan Resource Assessment and Development Project

**Std.:** Standard Deviation

**SUST:** Sudan University of Science and Technology

**SWIR:** Short wave Infrared

**TIR:** Thermal infrared
**TM:** Thematic Mapper

**TU Dresden:** Technical University of Dresden

**USGS:** United State Geological Survey

**UTM:** Universal Transfer Mercator

**VNIR:** Visible Near Infrared

**WGS:** World Geological Survey

**WHO:** World Health Organization