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Spectral Mixture Analysis for Monitoring and Mapping Desertification Processes in Semi-arid Areas in North Kordofan State, Sudan

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Preface

The interactions between people and environment are more challenging, rigorous and inevitable. Land degradation and desertification in drylands have been suggested to be the most alarming issue of current environmental problems. Importance of remote sensing in monitoring and mapping land degradation and desertification is extensively recognised and well developed in a wide variety of practical and scientific fields. The developments in satellite technologies and remotely sensed image acquisition and analysis offer effective opportunities for monitoring land cover change in such areas. Arid and semi-arid regions manifest a complex mosaic of vegetation cover, structure and phenology. Furthermore, arid regions endure intensive land use pressures and are highly sensitive to climatic perturbations. Remote sensing has been suggested for long time as a cost-effective method for monitoring change in arid environments. In this capacity, there are many efforts in the development of different remotely sensed methods for monitoring and providing information on dry land degradation. North Kordofan State, located in the central part of Sudan, is characterized by a fragile ecosystem which makes the region more vulnerable to land degradation and desertification risks. The region undergoes intensive land-use pressures and suffers from high sensitivity to climate fluctuations. Recurrent land degradation and desertification experienced by the region are presumably traced back to various practices such as changes in fire regimens, removal of vegetation, and over-grazing. Taking advantages of future hyperspectral imagery and developing methods such as spectral mixture analysis (SMA) are recently recommended as most suitable methods for vegetation studies in arid and semi-arid areas. Therefore, the current study is intended to improve the monitoring capability afforded by remote sensing to analyse and map desertification processes in North Kordofan using SMA technique. Three Landsat MSS, TM and ETM+ scenes covering the study area were selected for the analysis. Linear mixture model (LMM) and principle component analyses (PCA) were applied to determine and analyse land cover change. Eolain Mapping Index (EMI) was used to map and evaluate the soil erosion in the study areas that are subjected to wind erosion hazard. Interpretation of ancillary data and field observations verify the role of human impacts in the temporal change in both vegetation cover and sand soil. The findings of the study proved that SMA technique is powerful for characterisation and mapping of desertification processes in study area by providing direct measure of different land cover. Application of multi-temporal remote sensing data by the study demonstrated that it is possible to detect and map

desertification processes in the study area as well as in arid and semi-arid lands at relatively low cost. The study came out with some valuable recommendations and comments, which may contribute positively to reduction of sand encroachments as well as land degradation and desertification processes in North Kordofan State.

The study encompasses four parts including seven chapters. The first part, an introductory one, is devoted to the problem statement and rationale for the study, objectives and introduction to the study area. Part two reviews the theoretical and empirical background of the spectral mixture analysis (SMA). It summarizes the challenges and opportunities of application of this method in monitoring desertification in arid lands. Part 3 focuses on the methodological aspects of the study with special emphasis on the analysis, interpretation and classification of images, together with the field observations. The presentation and discussion of results are presented in part 4, which summarize, conclude, recommends and highlights the main limitations of the study.

The positive contribution provided by many individuals and several institutions in the completion of this study is highly appreciated and duly considered. With enormous indebt-ness to the Chair of Remote Sensing at the Institute of Photgrammetry and Remote Sensing, Dresden University of Technology, I am thankful for having such pleasant opportunity to do this study.

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M. A. Khiry, M.S.Dafalla, E. Csaplovics (2006). Mapping and Assessment of Sand Encroachment by Spectral Mixture Analysis in Arid and Semi-arid Areas: Case Study North Kordofan, Sudan (paper presented in The 6th International Conference on Earth Observation & Geoinformation Sciences in Support Africa’s Development, Cairo.

M. A. Khiry, E. Csaplovics (2006). Remote Sensing for Monitoring Drylands Environments Applications and Future Prospects, Case Study Sudan (paper presented in International Symposium on Dry lands Ecology and Human Security, Dubai.

M.A Khiry, E. Csaplovics (2007). Appropriate Methods for Monitoring and Mapping Land Cover Changes in Semi-arid Areas in North Kordofan (Sudan) by Using Satellite Imagery and Spectral Mixture Analysis. Paper presented in Fourth International Workshop on the Analysis of Multitemporal Remote Sensing Images, Leuven, Belgium.

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LIST OF ACRONYMS

ANOVA	Analysis Of Variance
AVIRIS	Airborne Visible /Infrared Imaging Spectrometer
CRC	Color Ratio Composite
CVA	Change Vector Analysis
DECARP	Sudan's Desert Encroachment Control and Rehabilitation Program
DN	Digital Number
EMI	Eolain Mapping Index
ENVI	The Environmental for Visualizing Images
ETM+	Enhanced Thematic Mapper
FAO	World Food and Agriculture Organization
FNC	Forest National Corporation
GIS	Geographic Information System
GPS	Global Position System
IFAD	The International Fund for Agriculture Development
IFOV	Instrumental Field Of View
LMM	Linear Mixture Model
LULC	Land Use/Land Cover
MESMA	Multi-Endmember Spectral Mixture Analysis
MODIS	Moderate Resolution Imaging Spectrometer
MSAVI	Modified Soil-Adjusted Vegetation Index
MSS	Multispectral Scanner
NDVI	Normalized Difference Vegetation Index
NIR	Near-Infrared
NOAA-AVHRP	National Oceanic and Atmospheric Administration-Advanced Very High Resolution Radiometer
NPV	Non-Photosynthetic Vegetation
PCA	Principle Component Analysis
R	Red band
RGB	Red Green Blue
RMS	Root Mean Square
SAVI	Soil-Adjusted Vegetation Index

SMA	Spectral Mixture Analysis
SRTM	Shuttle Radar Topography Mission
TM	Thematic Mapper
UN	United Nations
UNCCD	United Nations Convention on Desertification
UNEP	United Nations of Environmental Program
UTM	Universal Transverse Mercator
WEVI	Wind Erosion Vulnerability Image