Universität zu Köln
Geographisches Institut

# Applications of hyperspectral remote sensing in coastal ecosystems: A case study from the German North Sea

**Diplomarbeit**
vorgelegt von Benjamin David Hennig
Gutachterin: Prof. Dr. Frauke Kraas

Köln, im Dezember 2004

# Contents

# ABSTRACT / ZUSAMMENFASSUNG

The first chapter of the thesis deals with the evaluation of a methodological approach to identify habitat information in the intertidal zone of Helgoland/Germany. This chapter is focussed on spatial and spectral high resolution aerial imagery which covers spectral information from the visible and near infrared light. A semi-empirical analysis of the hyperspectral imagery is performed. It combines the extraction of significant spectral information derived from statistical data reduction and biotope mapping from the Alfred Wegener Institute (Bremerhaven). As methodological tool the remote sensing software ENVI from Research Systems is used.

Based upon these classification results, the integration of remotely sensed data in geographical information systems is examined in the second chapter. Here, it will be evaluated how the classified data can be integrated in GIS taking into account technical and methodological obstacles.

The GIS integration is used for accuracy assessment of the geometric quality of the ROSIS data. It will be proposed how methods in fieldwork on the ecology of the intertidal zone can be improved.

In the third chapter it is investigated whether using hyperspectral remote sensing methods as well as geographical information systems can successfully contribute to ecological research. To assess the general validity of an application of hyperspectral imagery in the study of coastal ecosystems, a second study from the Königshafen Bay intertidal at the island of Sylt/Germany is introduced and compared to the results from the Helgoland study. These results are generalised to deduce possibilities and limits of the integration of hyperspectral remote sensing applications in environmental monitoring systems. The contribution of the methods investigated in this thesis to geographical science will be evaluated as an important tool to research on interactions between man and environment.

---

Im Mittelpunkt der vorliegenden Diplomarbeit steht die Analyse und Entwicklung von Anwendungen hyperspektraler Fernerkundungsdaten im Bereich von Küstenökosystemen, die anhand einer Feldstudie der Insel Helgoland exemplarisch bearbeitet wurde. Die abgeleiteten Ergebnisse werden im Zusammenhang mit Umweltmonitoringsystemen diskutiert.

Das erste Kapitel der Arbeit untersucht die Möglichkeit der Identifizierung von Habitattypen im Gezeitenbereich. Verwendet werden hierfür räumlich und spektral hochauflösende Luftbilddaten im Bereich des sichtbaren Lichts und des nahen Infrarotbereiches. Die Analyse der hyperspektralen Daten des Sensors ROSIS erfolgt in Form einer semi-empirischen Analyse mit Unterstützung durch digitalisierte Biotopkartierungen des Alfred Wegener Instituts (Bremerhaven). Als Analysewerkzeug wird die Fernerkundungssoftware ENVI verwendet. Abschließend folgt eine Diskussion der Ergebnisse unter Berücksichtigung der Anwendbarkeit der Klassifikationsdaten für Biotopkartierungen sowie eine Qualitätsanalyse der Daten.

Im zweiten Kapitel wird untersucht, inwieweit sich Geographische Informationssysteme (GIS) und Fernerkundungsdaten in einem integrierten System vereinen lassen. Das ist einerseits von Bedeutung für die Entwicklung eines Monitoringsystems, in dem sich Daten vereinheitlicht darstellen und analysieren lassen. Andererseits kann ein derartiges System auch zu erheblichen Fortschritten bei der Feldarbeit führen, so dass auch der Aspekt der Geländetauglichkeit eines solchen Systems untersucht wurde. Bearbeitet wird diese Fragestellung, indem die Daten der im ersten Teil durchgeführten Fernerkundungsanalyse in ArcGIS mit dem Echtfarben-Luftbild und digitalisierten Feldkartierungen kombiniert, und so für den mobilen GIS Einsatz in einem D-GPS-gestützten PocketPC übertragen werden. Im Gelände wurden Fragestellungen zur thematischen und geographischen Datengenauigkeit der ROSIS Basisdaten sowie der Klassifikationsergebnisse eingehender untersucht. Zusätzlich werden weitere Anwendungsmöglichkeiten hyperspektraler Klassifikationsergebnisse sowie mobiler GIS Daten im Gelände geprüft.

Im dritten Kapitel werden die Ergebnisse auf generelle Nutzbarkeit in geo-ökologischen Fragestellungen des Gezeitenbereichs übertragen. Um eine allgemeine Nutzung von hyperspektralen Fernerkundungsdaten in Küstenökosystemen bewerten zu können, wird eine zweite Untersuchung vom Königshafen auf Sylt vorgestellt. Die Ergebnisse beider Analysen werden verglichen und generalisiert, um so allgemeine Aussagen zu Fernerkundungsanwendungen in Umweltmonitoringsystemen zu treffen.

---

# General Introduction

## 1 Objectives

The growing amount of remotely sensed data and the ongoing developments in the improvement of spatial and spectral resolution lead to high expectations for current research. These often inflated expectations are not usually fulfilled. To explore these expectations and help to bring them to a more accurate level, this thesis is a contribution to the evaluation of the rarely covered field of hyperspectral image analysis of small scale and heterogeneous biotopes in the intertidal zones of coastal areas.

With the availability of the first satellite based remote sensing sensors in the 1970s, remote sensing became an important and widely used method in earth observation for many scientific disciplines. The potential of satellite based remote sensing sensors has improved considerably since these early days – but as far as the improvement of technical issues is concerned, airborne remote sensing sensors are technically still a few steps ahead since they are cheaper to develop and provide faster results. Nowadays there are high resolution sensors with a sub-meter detailed resolution as well as sensors with a high spectral resolution. These so-called hyperspectral sensors cover more than 100 discrete spectral wavelengths (bands) providing information in many narrow spectral band rages. They cover the surface reflection of the electromagnetic spectrum from the visible light to the infrared regions and beyond.

On a regional level current hyperspectral sensors allow many features of the landscape to be detected due to their specific absorption ranges and spectral responses. In the 1990s, these approaches became more widely used. In particular, geological and ecological disciplines profited from the growing amount and increasing quality of landcover data.

Although many scientific disciplines benefit from remote sensing data, it is still the strength of geographical research to widen and optimise the use of remote sensing. Geographic tasks include the integration of the different scientific approaches to get better results from remotely sensed data by expanding them from the narrowed view of a single issue to a wider view. This thesis is an attempt to follow such an integrated view starting with the very narrow problem of specific biotope detection in the complex environment of an intertidal ecosystem.

It extends to general questions concerning mapping and monitoring issues in coastal ecosystems.

The base data for this thesis are remotely sensed imagery from the airborne hyperspectral sensor ROSIS (Reflection Optics System Imaging Spectrometer). The sensor has been developed by the German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt – hereafter DLR) and covers up to 120 spectral bands with a wavelength from 430 nm in the visible light to 850 nm in the near infrared region while providing a sub-meter resolution at the same time. Based on the problem of biotope mapping tasks the *Benthic Ecosystems*-section of the Alfred Wegener Institute for Polar- and Marine Research (AWI) in Bremerhaven/Germany realised a survey with the ROSIS sensor recording data from the intertidal zones of the island of Helgoland and the Königshafen Bay on the island of Sylt in the German North Sea. After a first test in September 2002 a second survey was carried out in September 2003 by the DLR.

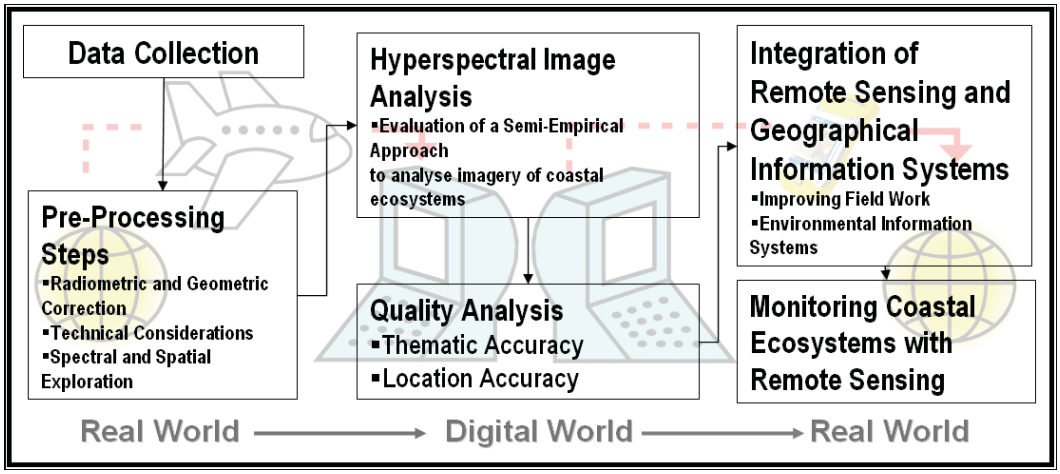


Figure 1: Working structure of the thesis

**The aims of the thesis are:**

- To investigate an appropriate method to extract main biotope information from hyperspectral images;
- To assess the thematic and location accuracy of hyperspectral data;
- To improve ecological fieldwork with remote sensing classification results;
- To estimate the general utility of remote sensing data in coastal ecosystems;
- To discuss contributions of remote sensing data to monitoring systems.

These issues will be investigated in three chapters following an approach leading from the real to the digital world and taking the results back to the real world (Figure 1). After the general introduction, chapter I evaluates the methods

of image analysis and applications of the classification results to the biotope conditions in the studied area. Chapter II focuses on accuracy issues, including spatial and thematic criteria. Chapter III discusses these methods of hyperspectral remote sensing with a general view on coastal ecosystems. A general discussion on remote sensing based monitoring issues concludes this thesis.