GeoS4S Module Geoinformatics for Coastal and Marine Resources Management

Salin, K. R.
Asian Institute of Technology, Bangkok, Thailand, E-mail: salinkr@ait.ac.th

Abstract
Marine and coastal environments continue to be impacted by both natural and anthropogenic factors in an era of changing climate. Given the vital ecosystem services they offer to humankind, these aquatic resources need to be monitored for more efficient planning and management. Coastal and marine resources are also being used for industrial aquaculture systems. Satellite remote sensing and geographical information system tools have numerous applications for management and conservation of these resources. The Marine Geoinformatics module encompasses a broad range of topics on marine geospatial techniques applied to coastal and marine environments. This paper is a summary of the module content, objectives, learning outcomes, lesson details, and evaluation scheme for this module.

1. Introduction

Diverse environmental stressors including changes in water quality, pollution, river-runoff, and dams or other barriers act upon aquatic biodiversity, globally. Changing climate resulting in erratic water temperature, rainfall and water level fluctuations in coastal and marine environments also pose significant challenges to their productivity. Marine capture fisheries operating in an open access regime often lack sound management plans, while coastal aquaculture and mariculture may have significant environmental impacts. Geographic Information Systems (GIS), Remote Sensing (RS) and mapping could be useful tools in the sustainable management of coastal and marine resources, coastal aquaculture, and mariculture facilitated by appropriate analysis, manipulation and interpretation of spatial and attribute data. This module covers some of these important topics for students to understand the concepts and identify the tools for efficient management of coastal and marine resources with the aid of RS and GIS.

1.1 Module Description

Oceans that cover over 70% of the earth's surface and their associated aquatic habitats provide major ecosystem services for the sustenance of human life. Efficient planning and management of these resources are of utmost importance given the continuing alterations that occur in these environments. Marine fisheries, coastal aquaculture, and mariculture are also important segments that need attention. While there has been an increased application of RS and GIS tools that are useful to maintain coastal and marine environments and to develop proactive plans for their efficient monitoring, these have not been compiled in a form that is easily understood by students coming from diverse backgrounds of marine environmental biology, and remote sensing and GIS technology. The objective of this module is to bridge this gap and develop a module that is easily appreciated by students with basic understanding of both topics.

This module outlines the basic concepts of RS and GIS and mapping coastal and marine enviornments, their fisheries and aquaculture, the software used, and data acquisition and analysis processes, to impart theoretical knowledge and practical skills on the application of GIS and RS in aquatic environment management and planning.

1.2 Learning Outcomes

- To apply Geographic Information Systems and Remote Sensing in the management of coastal and marine aquatic resources.
- To identify the GIS and RS tools for acquisition, analysis, and interpretation of data related to coastal and marine resource studies.
- To characterize physical and biological features of coastal and marine resources by application of GIS and RS tools.

- To apply GIS and RS tools in zoning for aquaculture/mariculture and to identify potential aquaculture sites in coastal and marine aquatic habitats.

2. Module Structure

2.1 Module Overview

This module consists of 15 lessons presented by power point slides, supplemented with relevant explanatory notes. There are five exercises for students to practice as self-study and five assignments for evaluation and grading by the instructor. Important references as required reading and other publications as optional study material have been provided at the end of each lesson presentation. This module that offers to provide credits equivalent to 6 ECTS is suitable for both online and classroom study, and mandates 150 – 180 h of student learning effort, excluding the exercises, class discussions, assignments, and group activities.

2.2 Summary of Lesson Content

The content and objectives of each lesson as part of this module is presented below:

- *Lesson 1: Introduction to the application of RS and GIS in coastal and marine resource management* - This lesson describes the salient features of marine resources and coastal formations, and outlines some of the major challenges of coastal and marine resources. It also introduces the basic concepts and applications of Remote Sensing and GIS in planning and management of coastal and marine resources.
- *Lesson 2: Processing of remotely sensed data for coastal and marine resources* - This lesson gives an overview of the preparation, analysis, and interpretation of remotely sensed data relevant to coastal and marine studies.
- *Lesson 3: Understanding the coastal environment – Sea Surface Temperature and Chlorophyll-a* - This lesson describes the significance, and analysis of Sea Surface Temperature and Chlorophyll-a concentration using remote sensing data from coastal and marine environments.
- *Lesson 4: Understanding the coastal and marine environment – Shoreline change and Suspended sediment concentration* - The impact of shoreline changes due to erosion and deposition on coastal environments, the significance of suspended sediment concentrations affecting marine life, and the techniques for satellite remote sensing of water turbidity are presented in this lesion.
- *Lesson 5: Coastal land resources mapping* - Techniques and applications of coastal resource mapping including image classification and validation for coastal areas, coastal land cover mapping, and change detection analysis are described in this lesson.
- *Lesson 6: Remote sensing techniques for mangrove and wetland mapping* - This lesson explores the remote sensing techniques for mangrove studies particularly applied to understand their species diversity, and to integrate mangrove spatial data and the available ecological knowledge of mangrove-environment interactions into the mapping process.
- *Lesson 7: Integration of RS-GIS data for mapping benthic habitats* - This lesson helps the student to understand the significance of benthic habitat mapping in integrated coastal zone management, and to apply appropriate methods to map seagrass and coral reef habitats.
- *Lesson 8: Application of WebGIS Tools for Monitoring Coastal resources* - The application of WebGIS tools for coastal monitoring tasks such as vulnerability assessment and planning, visualization of coastal flooding, coastal erosion, and impact of sea level rise are covered in this lesson.
- *Lesson 9: Monitoring Oil-spill and HABs using remote sensing and their impact on coastal and marine environment* - This lesson leads the student to understand the impact of oil-spills and the occurrence of harmful algal blooms (HABs) on coastal and marine environments, and then describes the remote sensing techniques to monitor oil-spill events, and for detection of HABs.
- *Lesson 10: Application of RS and GIS tools in the management of coastal and marine fisheries* - The application of RS and GIS tools in sustainable fisheries management and for fish habitat suitability modeling (FHSM) are described in this lesson. It also introduces the concept of an ecosystem approach to fisheries management.
- *Lesson 11: Integration of RS-GIS data for global monitoring of coastal and inland fisheries* - The lesson explains the use of GPS and WebGIS technologies for locating fishing activity that forms the basis of an established framework for global fish monitoring using real-time movement of fishing vessels, both in the inland as well in marine fisheries.
- *Lesson 12: RS and GIS for coastal and marine aquaculture* - This lesson introduces coastal and marine aquaculture, and describes the application of RS and GIS tools in coastal aquaculture and mariculture,

particularly to locate aquaculture sites in coastal and marine areas. It also provides the concept of an ecosystem approach to aquaculture.

- *Lesson 13: Applications of RS and GIS in spatial planning of coastal and marine areas for aquaculture* - This is a continuation of the previous lesson and describes the application of GIS and RS tools in zoning of potential aquaculture sites in aquatic environments. It also presents a case study to select potential aquaculture site using RS and GIS data.
- *Lesson 14: Case studies -Application of GIS and Remote sensing in coastal and marine resources* - The applications of RS and GIS techniques to solve real world issues related to coastal and marine resources management and planning are described in this session. A few case studies on Marine Protected Areas (MPAs) and Integrated Ocean Management Initiatives, and another on coastal pollution are provided.
- *Lesson 15: Modeling future scenarios of coastal and marine resources* - This concluding lesson describes the use of RS and GIS as a decision-making tool to assess future scenarios within the coastal and marine environments. It helps to develop a coastal and marine social-ecological framework to guide modeling and scenario analysis using RS and GIS.

3. Hands-on Sessions

In addition to the theoretical knowledge presented, the module is designed to provide hands-on learning to students for self-assessment by practical exercises using geoinformatics tools. The module includes five exercises associated with appropriate lessons that will help students to familiarize with the use of relevant software and to gain essential practical skills to apply RS and GIS tools in coastal and marine spatial planning and management. The five exercises and the associated lessons are given below.

- Exercise 1: Estimation of Sea Surface Temperature (Lesson 3)
- Exercise 2: Oceansat-2 OCM-2 Sensor data for marine water characterization (suspended sediments, Chl-a, turbidity, etc.) (Lesson 4)
- Exercise 3: Land use/land cover classification and mapping (Lesson 5)
- Exercise 4: Applying Remote Sensing techniques for mangrove mapping (Lesson 6)
- Exercise 5: Application of GIS and RS techniques for seagrass and coral reef ecosystems (Lesson 7)

The software used in the module include MS Excel, ArcGIS Desktop, Google Apps, ERDAS, etc.

4. Teaching and Learning System

The students undertaking this module are expected to have a basic understanding of RS and GIS, and background knowledge in coastal and marine resources management. The lessons in this module introduces the basic concepts of coastal and marine resources and the impact of various drivers of change, both natural and anthropogenic, that constantly modify these ecosystems. The applications of RS and GIS tools to monitor these ecosystem changes as a means of efficient planning and management is the prime focus of this module. Therefore the student learns to acquire practical skills to perform such decision-making operations on their own by way of five self-assessment exercises as hands-on practice in data acquisition, management, and output using both open source and proprietary software. Student learning is evaluated by five assignments that are graded by the instructor.

Case studies provided also enable students to approach real world problems in coastal and ocean zoning, spatial planning, and fish habitat suitability modeling. The students will also work on a mini project that will consolidate their skill for marine resource modelling and mapping.

5. Evaluation System

While the exercises are meant for self-assessment by students based on hands on practice, there are five assignments provided in the module that will help the instructor to evaluate student learning. These are graded based on a total scale of 100 marks. The assignments with their grades are shown below.

- Assignment 1: Application of GIS and RS in oceanography and fisheries (10 pts)
- Assignment 2: Types of GIS and RS data relevant to fisheries and aquaculture (10 pts)
- Assignment 3: Basic concepts and application of GPS in coastal and marine mapping (20 pts)
- Assignment 4: A Case study to select potential aquaculture sites using GIS and RS data (10 pts)
- Assignment 5: Mini project on coastal and marine resource modeling and mapping (50 pts)

The assignments will be given to students following each of the relevant lessons. For every assignment, an introductory essay will be provided to give the students an idea of the topics to be covered in the assignment. This will also help the instructor to evaluate the assignments.

6. Additional Notes

This module is a blend of topics covering coastal and marine environmental issues and the judicious application of remote sensing and geographical information systems for effective planning and management of these environments. The student is expected to have an understanding of the basic concepts and tools relevant to both subsets of topics. Free software will be used for the practice sessions as much as possible, while previously sourced data will be provided wherever required. Globally, marine capture fisheries has been stabilising over the past decade, and the significance of an ecosystem based fisheries management with the aid of RS and GIS tools have been explained in some of the lessons. Aquaculture in the coastal and marine environments is increasingly becoming popular as a major activity and therefore, some of the lessons have emphasized the concepts of ecosystem approach to aquaculture and zoning for suitable sites for aquaculture in the ocean. The students are expected to have additional reading materials provided at the end of each lesson.

Acknowledgements

This module forms part of the GeoS4S project co-funded by European Union (http://geos4s.zgis.at), which has provided an excellent opportunity for networking among colleagues from different countries. I would like to sincerely thank Dr. Shahnawaz, University of Salzburg, and Coordinator of the GeoS4S Consortium who has been the go-to-man for the entire project. Many serious interactions, fiery debates, and absolute fun were all part of most of the Consortium meetings, and for this, I am grateful to my colleagues and students from universities of Europe, China, and Thailand who have collectively contributed to the success of this project.

Bibliography

Chassot, E., Bonhommeau, S., Reygondeau, G., Nieto, K., Polovina, J. J., Huret, M., Dulvy, N. K. and Demarcq, H., 2011, Satellite Remote Sensing for an Ecosystem Approach to Fisheries Management. *ICES Journal of Marine Science*, 68(4): 651–666. URL: https://academic.oup.com/icesjms/article/68/4/651/650740/Satellite-remote-sensing-for-an-ecosystem-approach.

Meaden, G. J. and Aguilar-Manjarrez, J., 2013, Advances in Geographic Information Systems and Remote Sensing for Fisheries and Aquaculture. *FAO Technical Paper*. URL: http://www.fao.org/docrep/017/i3254e/i3254e.pdf.

Vanessa, S., Gimple, A., Gopnik, M. and Gee, K.., 2017, Aquaculture Site-Selection and Marine Spatial Planning: The Roles of GIS-Based Tools and Models. *Aquaculture Perspective of Multi-Use Sites in the Open Ocean*, 131–148. URL: https://link.springer.com/chapter/10.1007%2F978-3-319-51159-7_6.