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DOCTORAL THESIS OUTLINE

Student: Ayin Modina Tamondong **Date:** March 1, 2022

Department: Transdisciplinary Science and Engineering, School of Environment and Society

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Thesis Title: Integrated Remote Sensing and Coupled Watershed-Ocean-Vegetation Modeling for Seagrass Studies in Busuanga, Palawan, Philippines

Synopsis

Motivation:

The coastal water environment has long been considered as one of the most important natural resources. It is valuable to several essential industries such as transportation, trade, fisheries, aquaculture, and tourism. Unfortunately, with the rapid urbanization, economic development, population growth, and increasing threats of climate change, a need for environmental conservation and proper coastal management arises. Part of this threatened coastal environment is the seagrass ecosystem. Seagrasses are marine flowering plants that commonly grow on soft substrata (mud, sand) in shallow coastal waters. They are one of the most unique and productive ecosystems and they are a vital natural resource. Among the ecosystem services offered by seagrasses are providing coastal protection and serving as water filter. They trap sediment and excessive nutrients which improves the water quality, and they also act as barriers to reduce current velocity. However, excessive sedimentation may cause seagrass dieback. Light attenuation in the water due to reduced water quality has significant impacts on the survival of seagrasses. The rise in coastal developments increases the siltation deposited by rivers to the coastal environment which predicates an unclear future for seagrass meadows. In this study, an integrated remote sensing and modeling approach is developed for seagrass mapping, monitoring and assessment. Field observation, drone image analysis and coupled watershed-ocean-vegetation modeling were implemented to determine the impacts of river runoff on seagrasses in Busuanga, a small tropical island in the Philippines. Time-series analysis of satellite data and global models was performed to determine the long-term changes in the seagrass habitat and coastal environment of Busuanga.

Objectives: Develop a coupled watershed-ocean-vegetation model of Busuanga, Palawan, Philippines

- To assess the coastal ecosystem of Busuanga using field observations and remote sensing methods
- To simulate river runoff using the Soil and Water Assessment Tool (SWAT)
- To simulate the ocean circulation, water quality and sediment transport using the Coupled Ocean–Atmosphere–Wave–Sediment Transport (COAWST) Modeling System
- To simulate the dynamic growth and mortality of seagrass in response to the changing environment

Contents and Highlights

Chapter 1: A general introduction of the research including a discussion of the research background, significance, and objectives is presented in this chapter.

Chapter 2: This chapter explores the long-term variations in the coastal zone of Busuanga, such as temperature, sea level elevation anomaly, salinity, and chlorophyll through satellite data and global models. The aim of this chapter is to present the monitoring of seagrass habitat and coastal environment using time series analysis of datasets available in the google earth engine (GEE) platform such as Landsat, Moderate Resolution Imaging Spectroradiometer (MODIS), Sea-viewing Wide Field-of-view Sensor (SeaWIFS), HYbrid Coordinate Ocean Model (HYCOM). In this study, we found out that sea surface temperatures were increasing at 0.098°C per decade based on HYCOM data, while MODIS data showed an increase of 0.0045°C per decade. Sea surface elevation anomaly also increased at a rate of 0.0027 mm per decade, while salinity was decreasing at 0.0026 psu per decade, based on HYCOM data. On the other hand, chlorophyll-a concentration increased minimally through time, at a rate of 0.00013 mg/m^3 and 0.000037 mg/m^3 based on MODIS and SeaWIFS data, respectively. Using the Hansen et. al. global forest loss data available in GEE, we observed forest loss in Busuanga. Lastly, based on spectral unmixing results of Landsat images from 1987-2000, we observed a seagrass percent cover decline in Busuanga. The correlation analysis showed that seagrass percent cover was positively correlated with sea surface temperature, salinity, chlorophyll-a concentration from MODIS, and forest loss, while it was negatively correlated with sea surface elevation anomaly and chlorophyll-a concentration from SeaWIFS.

Chapter 3: This chapter present the results of the field survey conducted in September 2019 which aims to assess the coastal environment of Busuanga, particularly seagrass beds, through field observations and remote sensing techniques. This research aims to investigate the effects of river discharges on the distribution and abundance of submerged aquatic vegetation (SAV) in the study area. Based on sensor data, classified UAV orthophotos, and SAV field observations, it was found out that water turbidity is highest near the river mouth (Station A). In this station, there are fewer species of seagrass, no presence of seaweed, and low seagrass percent cover. However, as the distance from the river mouth increases, the turbidity decreases while the number of species increases, and the percent cover of seagrass and seaweed also increases.

Chapter 4: The development of a watershed model of Busuanga is presented in this chapter. The Soil and Water Assessment Tool (SWAT+) under the QGIS platform was utilized to determine the river outflow and sediment yield discharged from the watershed to the coastal area of the study site. The SWAT+ model produced various outputs such as hydrologic simulation, sediment discharges, nutrient concentrations, and several other products which is presented in this chapter.

Chapter 5: An introduction to the nested ocean modeling approach using Coupled Ocean–Atmosphere–Wave–Sediment Transport (COAWST) is discussed in this chapter. Three nested grids were created with varying resolutions and were utilized to produce a high-resolution coastal model of the study area. To validate the models, the simulation results were compared to existing satellite and global models

Chapter 6: This chapter discusses the coupling of SWAT+ and COAWST models to simulate the sediment transport from the watershed to the coastal zone of Busuanga. Simulation results from the nested model was used as initial and boundary conditions while the results from SWAT+ was utilized as river forcing. Presented also in this chapter is the creation of high-resolution bathymetric grid by combining GEBCO global bathymetry data and Sentinel 2A satellite-derived bathymetry. As validation, simulation results (with and without river input) were compared to water temperature (˚C), suspended sediment (mg/L), and u and v components of current velocity (m/s). The correlation and root mean square error of the simulated and observed parameters were calculated and results show that the addition of the river input considerably increased the correlation between observed and simulated suspended sediment from -0.432 to 0.640. This proves the effectiveness of coupling the SWAT watershed model results and COAWST ocean model.

Chapter 7: This chapter presents the development of a dynamic seagrass model to determine the effects of seagrass loss on current velocity and sediment deposition, as well as the response of seagrasses to sedimentation due to river runoff. A submerged aquatic vegetation (SAV) growth and mortality model developed by Kalra et al. in 2020 was adapted and modified for this research. Based on the results of the seagrass growth model simulation, plant density and above ground biomass increase as the distance from the river increases. This is similar to the results from the field and drone survey which indicate that seagrass percent cover increases as the distance from the river increases. The suspended sediment discharged from the river affected the seagrasses within the vicinity. Furthermore, the loss of seagrass in the simulation caused an increase in current velocity and suspended sediment in the water column as compared to the simulation scenario wherein seagrasses were present.

Chapter 8: This research presents the implementation of an integrated approach to seagrass studies using remote sensing and modeling and the final chapter summarizes and concludes the discussions in this manuscript. Prospective future studies related to this study is also presented in this chapter.

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