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GIS and Coastal Basemap Research Summer Internship with Clark Labs

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GIS and Coastal Basemap Research

Summer Internship with Clark Labs

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Zhuoyue Zhou

A MASTER'S PROJECT

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Submitted to the faculty of Clark University, Worcester,
Massachusetts, in partial fulfillment of the requirements for
the degree of Masters of Science in the Department of International Development,
Community, and Environment

And accepted on the recommendation of

Jie Tian, Chief Instructor

ABSTRACT

Po Hu, Zhuoyue Zhou

Our summer internship with Clark Labs will last for one and half of years, from October 2014 till the end of August 2016, while we've worked under the director of Dr. Ronald Eastman. The main duty for this project is to create a basemap for coastal line in three counties in the Southeast Asia, while during this summer, our duties were to wrap up the remaining tasks, such as adjusting the classification images based on the accuracy assessment results, combining all the images, making a final map, and calculating the area for each categories in each province of the three counties. Following the requirement of the M.S. GISDE program at Clark University, the following pages in this report describes in detail Clark Labs, the project that we were participated in and our reflections on this internship.

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Chapter 1: Introduction

We are graduate students majoring in geographic information science for Development and Environment (GISDE) at Clark University. Graduating from the GISDE program requires students to choose from three tracks: the internship track, research track or portfolio track. We decided to follow the internship track in order to gain more working experience, polish our skills and be prepared for our careers.

We have interests in remote sensing and GIS analysis. Since October 16, 2014, both of us started to work as Research Assistants at Clark Labs on a project called "Marine Habitats Mapping in Southeast Asia". The main purpose of our work was to create a baseline map for three countries in Southeast Asia: Cambodia, Thailand and Vietnam. It required us to use various skills including data processing, maintaining and GIS analysis. The project was planned to be finished by August in 2015 so that we decided to continue to work on this project and take it as our required summer internship. Many GISDE students worked in Clark Labs to strengthen their GIS skills by participating in academic projects in Clark Labs. Everyone in Clark Labs has a strong GIS background and it is easy to ask for help when facing technical troubles. In this view, Clark Labs is a great place to intern, which is one of the most important reasons why we decided to stay here during this summer.

This paper is organized in several chapters to describe Clark Labs as an organization, the projects that we worked on, and the life at Clark Labs. Chapter 2

describes Clark Labs and its current projects. Chapter 3 describes the projects we worked on over the year and through our summer internship. Chapter 4 focuses on the skills that we have learned from this project, the knowledge that we learned before and how it applied to this project. In Chapter 5 we assess this internship and provide recommendations to other students in our department.

Chapter 2: Description of Organization

2.1 Organization Introduction

Clark Labs is a small, non-profit organization that focuses on image processing software and geospatial analysis. Clark Labs started to develop the IDRISI Geographic Information System (GIS) software in 1987. Nowadays the IDRISI products have been used by professionals in a wide range of industries in more than 180 countries. The IDRISI products focus on raster image processing and contain various modules which are applied to solve real-world problems on both of global scale and regional scale. Besides developing general GIS software, Clark Labs also keeps long-time cooperation with such organizations as The Gordon and Betty Moore Foundation, Google.org, USDA, the United Nations, Conservation International and World Conservation Society and develops powerful customized tools as they need. (Clark Labs, 2015)

Since the organization is based within the Graduate School of Geography at Clark University, Worcester, Massachusetts, USA, it shares many resources with geography department and international, development, community and environment (IDCE)

department of Clark University. Ronald Eastman, the director of the Clark Labs, is also a professor of geography at Clark. There are many academic collaborations between Clark labs and Clark University. Software modules are built based on certain projects' requirements; frequently used tools in certain areas are packaged together in IDRISI Products. Clark Labs provides research assistant (RA) positions for master's and Ph.D. students who have GIS background to help them manipulate the software and work on academic projects. Students get experience in programming, image processing methods, critical thinking and problem-solving skills.

2.2 Organization structure

In this section, we will discuss the organizational structure of Clark Labs including the make-up of employees, what they do, and they skills they use. Over half of the employees at Clark Labs are Clark students who work part-time as research assistants. They are given different assignments including maintaining the software, reporting bugs, producing maps, making land use classification, analyzing land change, and so on. The remaining employees include full-time programmers, full-time GIS research analysts, part-time GIS research analysts. Most of the employees have a strong GIS background and programming skills. It is really common that people shift from one project to another or work on two or three projects at the same time. They often use their GIS and programming skills interchangeably in these projects.

2.3 Product introduction

2.3.1 TerrSet

Clark Labs has developed a GIS and Remote Sensing related software called TerrSet (formerly known as IDRISI). The first version was developed in 1987 by J. Ronald Eastman, a geography professor at Clark University. After that, Clark Labs continued to make changes to the software, and it now regularly releases updated version. The Land Change Modeler was an important development in the software, and it made its debut in 2009 in the IDRISI Taiga version. It was updated in 2012 during the IDRISI Selva release, and was able to support REDD projects – which allowed for the assessment of atmospheric impact of deforestation. Table1 is the history of the important history of the softwares. The newest version is called TerrSet, which incorporates the IDRISI GIS Analysis and Image Processing tools. During this internship, we mainly used the TerrSet to process Landsat8 images.

Year	Event
1987	Clark Labs has developed a GIS and Remote Sensing related software called TerrSet (formerly known as IDRISI). The first version was developed in 1987 by J. Ronald Eastman, a geography professor at Clark University.
1987-2009	the IDRISI Taiga released the 16 th version. IDRISI Taiga has image processing functions and contains several modeler for specific purposes. For example, the Land Change Modeler focuses on land change detection, impacts on biodiversity, and changes in the future.

2009-2012	the 17 th version of IDRISI was released: IDRISI Selva. This new version enhanced a few of the built-in models. For example, this version of the Land Change Modeler supports REED (Reducing Emissions from Deforestation and Forest Degradation) projects and allows the assessment of atmospheric impacts of deforestation.
2012-2015	In 2015, Clark Labs just released the newest version “TerrSet”, which incorporates the IDRISI GIS Analysis and Image Processing tools

Table 1. Major history of the softwares

TerrSet constellation includes eight modules. The *GIS Analysis System* provides several fundamental tools for GIS analysis (TerrSet is mainly focused on raster data process). It also provides scripting environment such as Python, and the flexible application programming interface, which allows users to code scripts for tedious tasks.

The *Image Processing System* is used to process the image including restoration, enhancement, transformation and classification. During this internship, we used pan merged tools to upgrade the image resolution, and then used the soft classification procedures to classify images.

The Land Change Modeler module, which is used to analyze land cover change, can generate graphs and maps about the change between two maps, include gains, losses, persistence and net change of each category for the input map. Also this module could map the transition potential images based on the change during the past and make predictions for future land use. For the change prediction, this model can map a hard prediction map based on some scenarios such as multi-objective land competition model, or a soft

prediction map which is a vulnerability map with the value showing the possibility of the change to each category in the future. TerrSet enhanced the LCM to cooperate well with the REED project.

The Habitat and Biodiversity Modeler (HBM) is used to model the species distribution or the suitability of habitat, the effect of land cover change on habitat, and can also calculate the biodiversity.

GeOSIRIS is a tool developed for national-level REDD (Reducing Emissions from Deforestation and forest Degradation) project, which quantifies and maps the impacts of REDD on different aspects, such as carbon emission, deforestation. Users can specify some parameters such as the price of carbon, carbon emissions, and some economic parameters, and then GeOSIRIS would determine the effective opportunity cost, and generate a map of potential agricultural revenue and some maps showing expected carbon emissions with and without the proposed REDD policy.

Ecosystem Services Modeler is used for assessing the value of natural capital for sustainable development, it provides 15 ecosystem service models. The data used in this model can be derived from Land Change Molder or Climate Change Adaptation Molder in TerrSat.

Earth Trend Molder is a tool for analyzing time series data of remote sensing images. Users can assess long term climate trends, seasonal trends and extract patterns in time and space among these time periods. Also ETM can also be used for noise removal and deseasoning in order to extract patterns without the effect of seasonality.

The Climate Change Adaptation Modeler is a tool for modeling future climate change and its affections to the rise of global sea level, suitability of crop for over 2700 species and species distribution.

2.3.2 Land Change Modeler v.2.0 for ArcGIS

Clark Lab received funding from ESRI to create Land Change Molder extension for ArcGIS. This molder is compatible with ArcGIS 10.2 and later. It has similar feature with the Land Change Molder inside of Terrset.

2.4 Current projects

Now that we've explained Clark Labs and the products that it develops, here are two examples of ongoing projects.

2.4.1 Marine Coastal Mapping Project

In March 2014, Clark Labs received funding from Gordon and Betty Moore Foundation¹ in order to create a baseline map of coastal areas which would indicate the shrimp distribution in Southeast Asia, Vietnam, Cambodia and Thailand. This project mainly uses Landsat 8 imagery for classification, and then provides probability maps and risk maps for the future conversion to shrimp farming from other categories such as cropland, mangrove, and salt production. This project required the classification of 42

¹ The Gordon and Betty Moore Foundation was established by Intel co-founder Gordon E. Moore and his wife Betty I. Moore. This foundation is mainly founded projects that will improve the life quality for future generations, such as environmental conservation.

images, and also required pan sharpening some critical bands for water penetration in order to analyze the marine categories.

2.4.2 Cloud-based Version of Land Change Modeler for ArcGIS

In February 2014, a project with ESRI was established. This is a cloud-based version of the Land Change Modeler, which provides various tools for land change detection, prediction and the impacts of these changes. It can also model the influence of land cover change on carbon emissions and also has the ability to estimate the land change impact on biodiversity and habitat.

ESRI is a company, which supplies Geographic Information System (GIS) software ArcGIS. It operates on desktop, server and mobile platform, and supports editing, analyzing, sharing and developing geographic information data, especially vector data. The company has over 80 international distributors and is a prominent company in GIS and related fields.

2.5 Organization Working and Culture Environment

The working space is quite bright and big, spanning three floors. The first floor is equipped with 8 computers in the open area for students who work on software maintenance and report bugs. The second floor has 3 large offices for research groups and one small office for a programming group. The third floor is the conference room with the kitchen by the side. On Friday all staff have lunch together and order food from different local restaurants. During the summer, we have international food festival every Thursday,

and people make food from their home countries to share with everyone. We also share local music and bring interesting stories about their countries.²

Chapter3 Southeast Asian Land and Marine Habitat Mapping Project

3.1 Background Information

This project was funded by Gordon and Betty Moore Foundation and its aim is to create a baseline map of coastal areas in Southeast Asia, include Vietnam, Cambodia and Thailand, which would indicate the distribution of shrimp. This basemap could be combined with the historical classification results to create a transition potential map, which represents the potential probability of one land-cover type for conversion to a different land-cover type under a specific scenario.

3.2 Study Area

The study area for this project is the coastal zone of Thailand, Vietnam and Cambodia. Thailand and Vietnam are among the five largest shrimp production countries in the world (FAO^[1], 2014). Cambodia was chosen because it has the important mangrove resources which face many threats including disturbance for farming shrimp (Song, 2004^[2]

² Pictures can be Clark Labs Facebook page. (<https://www.facebook.com/Clark-Labs-464095610192/timeline/?ref=mf>)

). Coastal zones are defined in this project by the European Environment Agency (2006^[3]). All land areas that are less than 10 km from the coast would be considered as coastal zone. For ocean, areas that are less than 10km from the mainland coast or less than 30 km in depth would be considered as part of the coastal zone. However, in this definition, the Red and Mekong Deltas would be affected, based on the information related to salt intrusion in these regions (Anh Duc, 2008^[4]; Arli, 2007^[5]; Vu and Bui, 2006^[6]); this project allows a maximum extension of 60 km from the coast for the land coastal zone. The whole study area was covered by 42 Landsat 8 images, ranging from April 2013 to January 2015.

For statistical purposes, we want to analyze the area of each category inside of each province of the three countries, thus we need a study area map with provinces' information. We will explain it in detail later in this chapter.

3.3 Work before summer

3.3.1 data

There are a total of 42 images used for this project (fig. 1). All the data is collected from NASA Earth Explorer to cover the study area. (table. 1) We processed 39 images before the summer and 3 images during the summer. A special model in TerrSet is created to preprocess the data for this project, including correcting atmospheric effects and creating pan merge bands and log ratios bands. In order to classify the small clusters, we used the pan merge technique to upscale our images from 30 meter resolution to 15 meter resolution. This technique merges the 15 m resolution panchromatic band with bands 3, 4

and 5 in GIHS system and then retransforms it to RGB system creating new bands in 15 meter resolution. The model also creates log ratio bands $2/1$, $3/2$, $4/3$ which are used for marine habitats classification. Band ratios are depth invariant providing constant spectral signatures of marine features in the shallow clear water. In addition, they are sensitive to turbidity; thus the property is used to extract the turbidity.

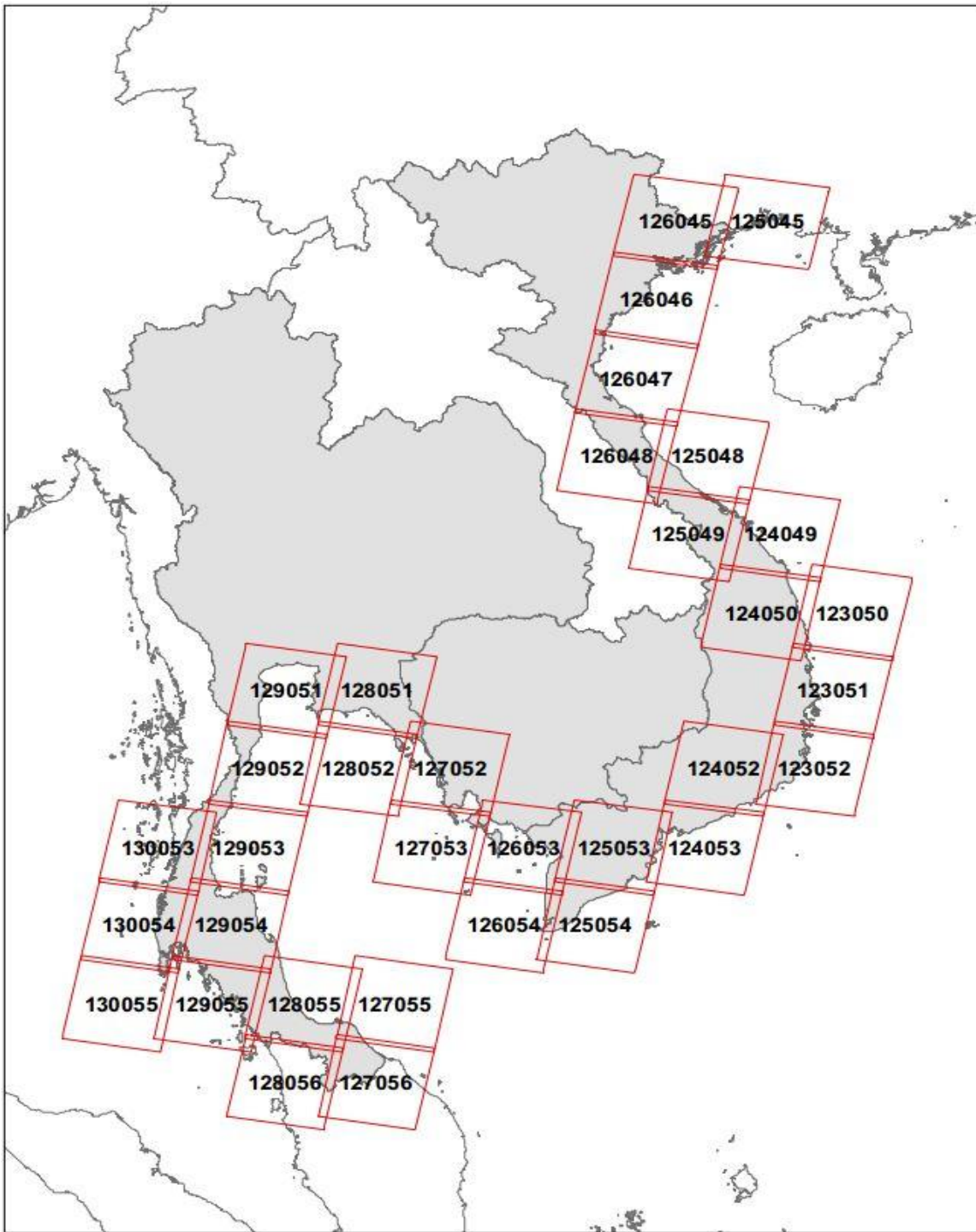


Figure1. Landsat Images used in this project

3.3.2 land classification and marine classification

Figure 2 below shows the categories mapped in this project. During the project of classification, we mainly use MAHALCLASS module inside of TerrSet, which is a soft classifier. Based on the training site information for each category, the output is a set of images showing the probability of each pixel relative to the category described by the training sites (TerrSet Help Document^[9]). After referring to Google Earth high resolution maps, we adjusted the classification results and chose a proper threshold to get the final classification for that category. However, for some categories such as pond aquaculture, there are different types (wet pond and dry pond), which would then have different spectral signatures. For those categories, we digitized most of them based on Google Earth maps.

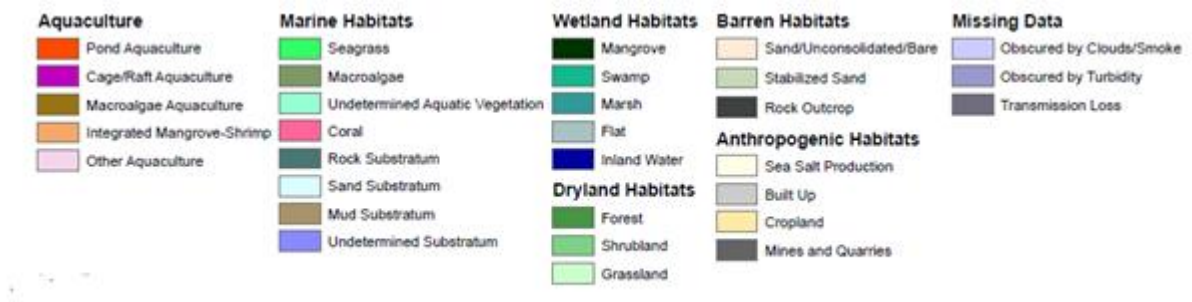


Figure2. Categories Name for this Project

For marine categories, we use 3 log ratio images created for adjacent band pairs in the visible to create color composite map, and chose training sites for classifying marine categories, such as seagrass, coral and turbidity. As mentioned before, the log ratio bands are sensitive to turbidity under the water, we can just set a threshold of one band and reclassify it to distinguish turbidity and other categories.

3.3.3 Accuracy assessment

In order to estimate the classification result, an accuracy assessment was undertaken on the land classifications. Google Earth was used as the reference image. For each images, we created 200 to 400 random samples depending on the area falling into the study area. The near coastal zone was given more samples, allowing us to have enough samples in pond aquacultures, the majority of which are located within 2.6 kilometers from the coast. We recorded the ground true category and classified category of each sample and finally provided specific error matrix for each scene and an accuracy assessment report for the whole study area.

3.4 Responsibilities for summer internship

Our main responsibilities in the summer were: (1) to evaluate the classification results and fix the clusters which don't meet the required accuracy level; (2) to fix study area mask, and attach the province information inside of the file for statistical purpose; (3) to merge all the scene classification images into one image using the *concat* module. and calculate the area statistic at the province level; (4) to provide a well formatted map showing the "concat" classification, and hold all useful files in the web for better communication.

3.4.1 Fixing clusters based on accuracy assessment

Based on the land cover accuracy assessment, we found that most errors occurred in the clusters of shrubland, stabilized, sand, and salt. All the samples were stored in one excel sheet and we used the filter to find in which scenes the errors occurs most. Then we allocated to the specific images and created new train site to reclassify the low accuracy clusters. Some parts of the scenes are occupied with different types of errors; the classifier can hardly provide satisfied results. In this situation, we need to digitize the clusters based on different images including google earth images, natural color composites, false color 475 composites which are specially used for identifying mangrove. The following table is showing how the accuracy is improved.

Category	User's Accuracy	Producer's Accuracy
Pond aquaculture	94%	86%
Mangrove	94%	92%
Integrated mangrove-shrimp	95% (94%)	76% (96%)
Cropland	87%	93%
Forest	93%	88%
Built-up	81%	83%
Shrubland	85% (87%)	53% (66%)
Sea-salt production	90%	81%
Sand/unconsolidated	67% (80%)	76% (81%)
Stabilized sand	88% (90%)	82% (87%)

Table 2. User's and producer's accuracy for the major land categories

**Figures in parentheses indicate revised accuracies after a reassessment*

3.4.2 Mekong integrated mangrove shrimp fixing

The Mekong has a unique category of *integrated mangrove-shrimp*, which is hard to classify. This category is a mixture of pond aquaculture and mangrove. In the integrated shrimp-mangrove aquaculture system, mangroves are allowed to grow naturally or are planted in purpose to enhance the habitat for cultivated species, such as shrimp. The spectral signatures are not constant within that category due to the mixture of water and mangrove, thus we cannot use Mahalanobis Method to modify it. Instead we refer to several papers which mainly focus on analyzing the distribution of aquaculture in Mekong Delta to adjust the result.

This area has many patches of mangrove, which are mandated to occupy at least 60% of the aquaculture farm (although farms that are in transition to this pattern will have lower percentage). The integrated mangrove-shrimp aquaculture farms are designed to maintain a high degree of coastal protection while simultaneously providing farm income from mangroves and pond aquaculture (Ha et al., 2014). However, some patches of the mangrove are bigger which we would then regard as mangrove instead of integrated mangrove-shrimp farm. As we mentioned before, this category has different spectral signature, we use a linear spectral unmixing to separate it from extensive pond aquaculture and remnant patches of mangroves. If the pixel has a value equal or higher than 75% membership in the mangrove class, it would be designated as mangrove, then we group the contiguous pixels together, and assigned the groups to be mangrove if their area is greater than 0.5 ha. For distinguishing the integrated mangrove-shrimp from intensive pond

agriculture, we could digitize the pond aquaculture category by referring to high resolution Google Earth maps. Figure 3 below is the fixed classification result in Mekong area.

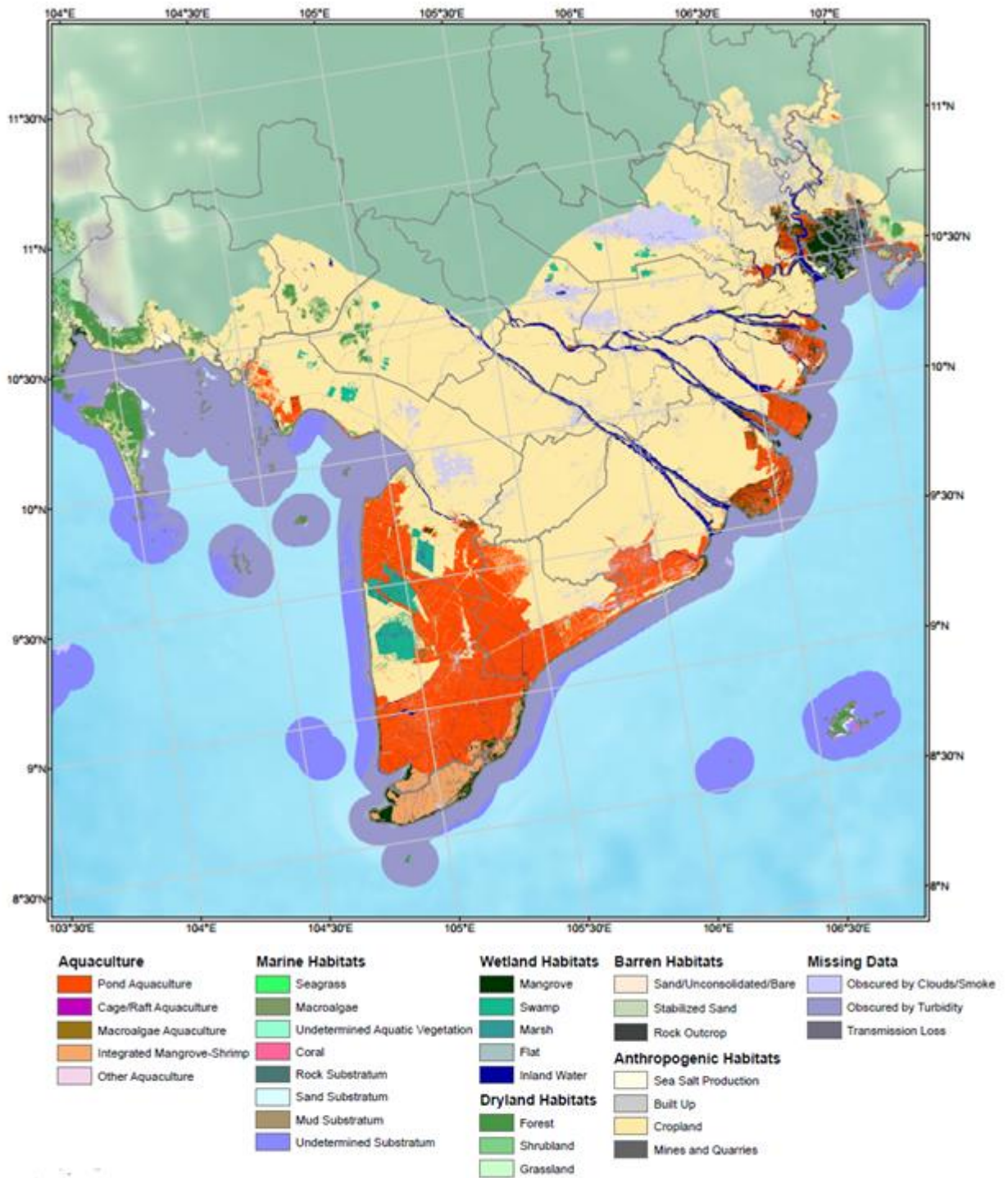


Figure3. Mekong Classification Map

3.4.3 Fixing the boundary

We have found that the previous study area mask is not accurate in the intersection with other countries, such as the border of Vietnam and China, the border between Thailand and Malaysia. Referring to the Open Street Map in ArcGIS, we adjusted our study area mask, digitized the boundary with other countries, rasterized the shapefile into TerrSat, and overlaid with the “Concat” result map.

Since we want to analyze the area of each category in province level, we need to join the province information on the study area mask shapefile. The Open Street Map also contains the province information in the marine area. We have downloaded the province boundaries shapefiles and the EEZ shapefile (the Exclusive Economic Zone extends no more than 200 nautical miles from the territorial sea baseline)referred to the Open Street Map. We can then digitize the province boundaries in the marine area, thus extending the coastal province boundaries to cover the entire study area.

3.4.4 concat and statistic calculation

When the classification image of each sense reached required accuracy level, we mosaic total 42 images into one huge image for statistical calculation. The major problem is that each scene is overlapping with its neighborhood scene. To deal with it, we compare the overlapped areas and make an order to mosaic images to make sure land cover transmits smoothly from one sense to another. Some overlapping showed great gaps which were caused by seasonality, air condition, cloud cover, and edge effect. To smooth the gap,

we clipped some parts from different scenes to make up the overlapped area. After fixing the overlapping areas between scenes, we used the “Concat” module to combine the images in certain order. The higher accuracy images would be put on the top.

Finally we applied the province boundaries to the concatenated classification images and calculated the area of each cluster of each province. The interesting thing is that area of mangroves in Vietnam and Thailand is 18% larger than the national survey.

3.4.5 Mapping

Our study area is the coastal zone of three countries, which is a large area. In order to better show the classification results, we decided to divide the whole study area into six regions. We captured the longitude and latitude for the four corners, and created a polygon shapefile with the an attribute table describe the FID for the six regions. We created two dataframes, one showing the zoom in level results, while the top right corner dataframe is a overview image showing the whole study area, with a red box showing the corresponding position of the zoom in level window. Using the “Data Driven Pages” tool to link the attribute table of the six regions as the index number for the page in series. (fig. 4 is one result map for our project)

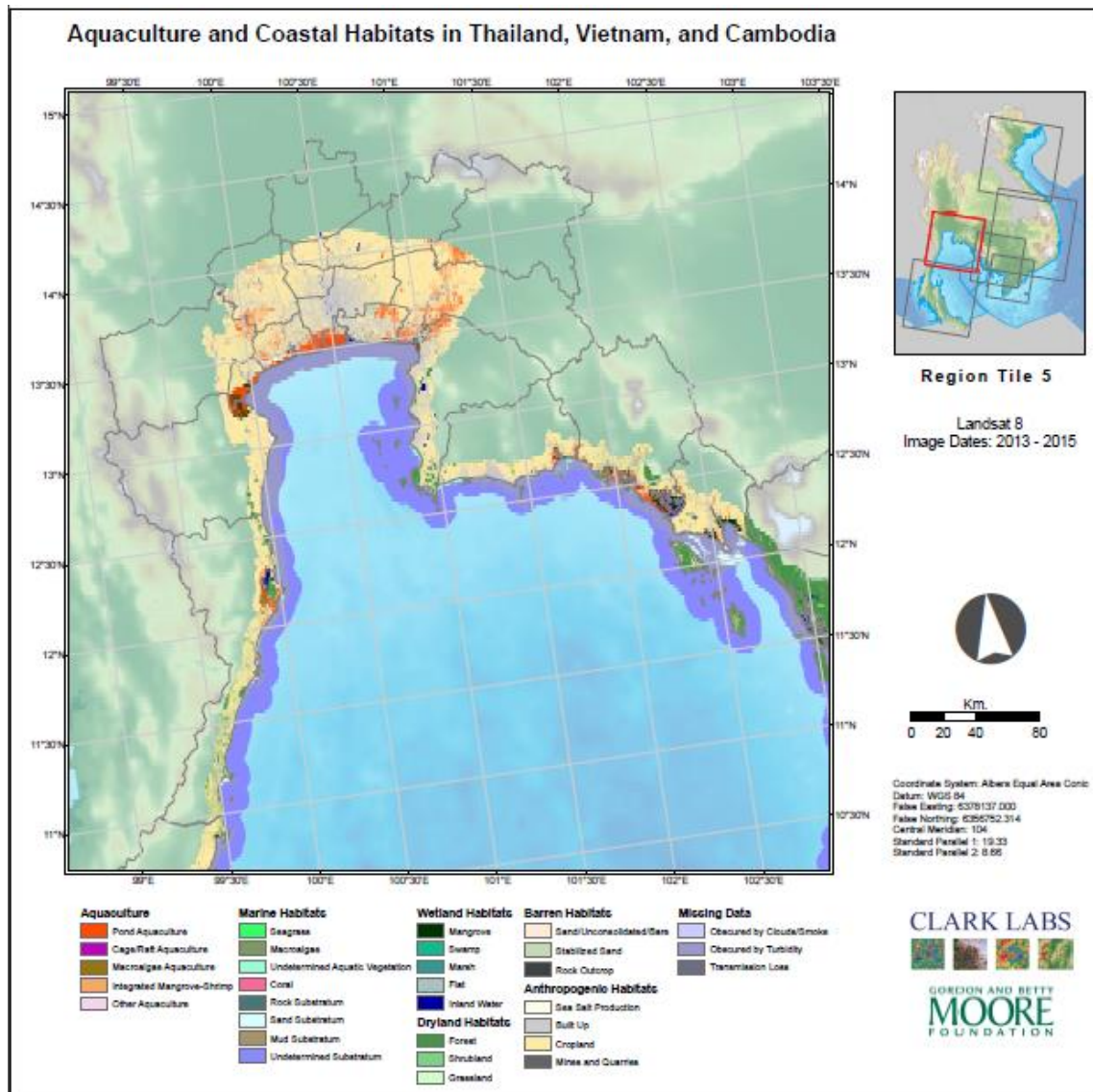


Figure4. Final Output Map for this Project

3.5 Summary

The final product of the project is a base map with the classification results of the coastal zone. We have created six classification maps in pdf format. Later on we will

upload the “Concact” classification image to a map server and using ArcGIS online to create a web page and share the data.

The final product of the project is a base map with the classification results of the coastal zone. We have created six classification maps in pdf format. Later on we will upload the “*Concact*” classification image to a map server and using ArcGIS online to create a web page and share the data with people.

This base map could be used for transition analysis in combination with other time point classification maps. Another person in our group focused on creating the transition potential maps, which represent the potential of one land-cover type for conversion to a different land-cover type under a specific scenario. He classified some categories, such as pond aquaculture, mangrove, salt-production using historical Landsat images, and using the Land Change Modeler for Ecological Sustainability (LCM) within TerrSet geospatial monitoring and modeling system to map the transition potential for each Landsat scene (Eastman 2015^[7]). Using a Multi-layer perceptron (MLP) neural-network, LCM analyzes historic land-cover change with explanatory variables to generate a soft prediction of transition potential. (Cunningham 2015^[8])

Chapter 4 Internship Assessments

Our internship in Clark Labs during this summer was a great learning experience, which is one of reasons that we choose to stay there for the following fall semester. This internship required basic GIS skills and the ability to learn skills for specific tasks which

we gained in our undergraduate and graduate study. During this internship, we gained knowledge about remote sensing, such as image preprocessing methods, Mahalanobis Classification, and using ArcGIS to create a series of beautiful maps.

We learned how to use a false color composite to define the spectral signature for each category based on their characteristics. As mentioned before, one of the most important categories in this project is the Mangrove, which grows in water, thus we could use Band 4, Band 7 and Band 5 as the Blue, Green and Red for composite. (Band 4 is the Red band for Landsat 8, Band 7 is the Shortwave Infrared (SWIR) and Band 5 is the Near Infrared band (NIR)). Wavelengths would be absorbed by water in the visible bands, and get relatively higher reflectance in the SWIR band, thus the color for Mangrove in that false color composite is dark red. That is very distinguishable.

For the map production, we have strengthened our skills in ArcGIS; we imported the original map into ArcGIS, formatted the legend, and created series map using “Data Driven Pages” which can link the map fusion table with the index of the polygons. We have learned ArcGIS analysis skills, which are very helpful when we adjusted the study area boundary for this project, as well as when we extended the province boundary based on the information provided in province index. Since the study area is very large, processing the raster dataset may take a long time, but converting to vector file and processing in ArcGIS saved a lot of processing time.

The GISDE program provides intermediate and advanced courses using Idrisi Products which are really helpful to our work. Most of the technology we used in

clustering and mapping are what we learned in the course introduction to Remote Sensing. Python skills were also quite helpful. When dealing with the accuracy assessment table, we had troubles creating an assessment on the whole area. The Terrset only provided a module to produce an error matrix on one image. To complete the accuracy assessment of the whole study area, we had to merge all the classification images and samples images which would take long time. Instead of doing an assessment in this way, we create a python script to produce the error matrix based on the ground true table we made. It is much easier to merge the table than images, and the computing speed of our python script was way faster than using the ErrMat module.

The most impressive thing we learned from the internship is how to increase the efficiency in our work. Cooperating with the developers definitely brought us new understanding. When we tried to use certain modules, Ronald Eastman would help to explain the efficiency and logic of the modules and suggest how to use these modules. During the internship, we learned that processing a table is somewhat better than processing images because image processing is more time consuming than table processing. When we tried to summarize an area on the image of whole study area for each province, we do not use the summary function in the area module which would calculate crosstab information from two images. Instead we used *simply overlay module* to combine the images of the province boundary and classification results and then produce a table to store area information from the combined image. Finally we split the information of provinces and classification in the table. The process was quite faster and saved time. To

accomplish the task in the most efficient way can be hard but it is worth the effort; in the future, we need to think about efficiency as an important factor when we work on projects with large study areas.

For our future careers, we want to focus on data processing and analysis-related tasks using Python script to automate the procedure. This internship helped us to better understand the logic of a project, the steps of data processing, analysis and some remote sensing knowledge.

Chapter 5. Conclusion and Recommendations

We would definitely recommend this internship for other IDCE students. Clark Labs is a great place to work because of the faculty members are all prominent in the GIS fields and it has a fun work environment. We enjoyed International Food Festivals every week, three or four people would prepare lunch for the whole group, we gathered together and chat with each other. Clark Labs allows students to have a flexible schedule. Part-time students can fully customize their working schedule and use spare time to work on another part-time internships.

We appreciated having this internship opportunity to work on this project at Clark Labs, we have learned a lot about remote sensing as well as how to cooperate with group members. The weekly group meeting was very useful; we talked about what we did, and our new findings. Communication is very important, especially for group work.

We felt this internship was a valuable working experience for our future careers. During this internship, we were given a lot of freedom to apply the knowledge that we learned from Clark University or from our undergraduate study, and we think this internship helped us recall a lot of previous learned knowledge.

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