Coastal Resources Mapping in the Philippines

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ABSTRACT

The Philippines, being an archipelago with more than 7,600 islands, is considered as home of rich and high productive marine habitats. Despite their economic and ecological importance, reports on the declining coastal resources have increased in numbers in recent years. With the advance technological approaches on research such as remote sensing and geographic information system, mapping the coastal resources in the Philippines is not too farfetched to obtain the inventory and spatial extent information which are important for resource management. This paper describes the nationwide mapping of coastal resources in the Philippines using remote sensing, and discusses how these maps could contribute to the conservation and protection of these resources.

The Nationwide Detailed Resources Assessment using LiDAR Surveys Program (Phil-LiDAR 2) was implemented by fifteen universities throughout the country which aimed to produce high resolution coastal resources maps using the available LiDAR and other remotely-sensed datasets. Object-based image analysis (OBIA) technique was applied to extract the resource features based on its spatial and spectral attributes. Image was first segmented into objects based on homogeneity criteria. A supervised classification was performed using a support vector machine (SVM) classifier to categorize the objects into different classes. Field surveys to collect training and validation points were done to calibrate the classification process and validate the output. The maps produced were distributed to stakeholders once standards of accuracy had met. These would be beneficial for the planners and coastal managers by providing comprehensive spatial and land cover information which could be used to extract other science-based information such as identifying vulnerable coastal resources to impacts of climate change and anthropogenic disturbance. The maps would also aid them in monitoring activities and management strategies. Overall, this is expected to recognize the importance of space technologies in mapping the country's natural resources.
Keywords: remote sensing, object-based image analysis, LiDAR, coastal resources

1. INTRODUCTION

1.1. The Philippine Coasts

The Philippines, being an archipelagic country with more than 7,600 islands and located at the apex of the Coral Triangle also known as the World's Centre of Marine Biodiversity, is rich in coastal ecosystems characterized by dense mangrove forests, and large areas of seagrass and coral **[1]**. With approximately 60% of the country's total population living along coastal communities **[2]**, the people depends on the country's coastal and marine resources for sustainance and livelihood. Despite its ecological and economic services for the people, the coastal resources of the country continue to experience serious threats of degradation over the years, mainly because of the unsustainable human exploitation but progressively by global climate change-related stressors. With the growing concern of protecting the country's coastal resources, there is a need to accurately map the coastal environment to provide rapid assessment of these habitats which is critical for developing management strategies and marine spatial planning. Mapping of coastal resources using the traditional field-based method produces high accuracy. However, to cover a larger area, the activity would be expensive and would need a longer time. Approach on researches using latest technologies such as remote sensing provides information that could support the wide-scale mapping of these resources for monitoring, protection, and conservation.

Light Detection and Ranging or LiDAR technology has become increasingly well known as an accurate mapping tool. The use and demand for the technology increased because of its ability to map or spatially reference physical features at high accuracy for a large geographic area. This technology was used to map the Philippines' coastal resources along with hyperspectral and multispectral images.

1.2. Nationwide Coastal Resources Mapping

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) implemented a directed research program entitled "Detailed Resources Assessment using LIDAR (Phil-LiDAR 2)". It was a three-year program which started last July 2014. The Phil-LiDAR 2 Program aimed to complement on-going programs of government agencies (e.g. Department of Agriculture, Department of Environment and Natural Resources, Department of Energy, etc.) by utilizing LiDAR data and developed methodologies for extracting resource features from LiDAR and other remote sensing data for various applications such as production of high value crops, irrigation assessment, coastal resource conservation, aquaculture production, forest protection and discovery of renewable energy sources. As part of the program's objective, high resolution resource maps and vulnerability assessment maps for high-value crops and coastal resources were produced to aid in the recommendations addressing future local supply and demand in agriculture, coastal, forest, and renewable resources.

The program was driven by the collaborative efforts of the fourteen (14) other State Universities and Colleges (SUCs) and Higher Educational Institutes (HEIs) in the different regions of the country. The SUCs and HEIs were clustered into three, representing the major groups of islands in the Philippines: Luzon cluster, Visayas cluster, and Mindanao cluster. The fourteen partners were Mariano Marcos State University (MMSU), Isabela State University (ISU), Central Luzon State University (CLSU), Mapua Institute of Technology (MIT), University of the Philippines Los Banos (UPLB), Ateneo de Naga University (ADNU), University of the Philippines Cebu (UP Cebu), University of San Carlos (USC), Visayas State University (VSU), Ateneo de Zamboanga University (ADZU), Central Mindanao University (CMU), Mindanao State University – Illigan Institute of Technology (MSU-IIT), UP Mindanao (UP Min) and Caraga State University (CSU). These SUCs and HEIs committed to deliver the coastal resources maps for their assigned provinces and municipalities. They also coordinated with the provincial and local government of their study areas in conducting field surveys and gathering secondary data.

Figure 1. Phil-LiDAR 2 partner universities and their assigned regions

2. OBJECTIVE

The Program was composed of five components: Project 1: Agricultural Resources Extraction from LiDAR Surveys (PARMap), Project 2: Aquatic Resources Extraction from LiDAR Surveys (CoastMap), Project 3: Forest Resources Extraction from LiDAR Surveys (FRExLS), Project 4: Development of the Philippine Hydrologic Dataset for Watersheds from LiDAR Surveys (PHD), Project 5: Philippine Renewable Energy Resource Mapping from LiDAR Surveys (REMap). This paper discusses the Project 2 of Phil-LIDAR 2 Program. The Project 2 or the Aquatic Resources Extraction using LiDAR Surveys aimed to provide an updated and detailed inventory of high valued coastal resources in the Philippines by developing methodologies for mapping such resources using LiDAR and other geospatial technologies such as optical imagery and multi beam echo sounder. Specifically, the project aimed to develop algorithms and workflows for extracting and characterizing coastal resources using LiDAR and other remotely sensed data, and field measurements; production of high resolution and high accuracy maps of coastal resources; and vulnerability assessment of different coastal resources. Among the expected outputs of the Project were the algorithms and workflows for data processing, output maps, geodatabases, and spectral library of various coastal resources such as mangroves, corals and seagrass.

3. METHODOLOGY

3.1. Data

LiDAR is an emerging remote sensing technology which is used to accurately map the topography of the Earth's surface. It is an active type of remote sensing that uses laser pulses to compute for distances of objects on the ground. The distance is computed by measuring the time it takes for a laser to hit the ground and sent back to the sensor. The aircraft is installed with a laser device which scans the Earth, the global positioning system receiver that tracks the altitude and position of the aircraft at the time of measurement, the Inertial Measurement Unit that records the attitude or orientation (yaw, pitch, heading) of the plane which is important for accurate elevation computation, and a computer and software for navigation and flight management and data records and storage.

Topographic LiDAR uses near infrared light to map the ground features, while the bathymetric LiDAR system uses both green and near infrared lights. The bathymetric LiDAR system collects simultaneous land and water depth measurements. An aerial camera is also mounted on the aircraft to capture orthophoto simultaneously with the acquisition of LiDAR point cloud.

In the Philippines, the LiDAR system was set to produce an up-to-date and detailed elevation dataset with 1-meter horizontal resolution (2 data points per square meter) for flood plain areas, and 20-centimeter vertical accuracy. This was to cover major river systems in the country for the purpose of flood hazard assessment. On the other hand, the data was also used to produce inventory and assessment for natural resources such as agricultural, coastal, forest, and renewable energy. The LiDAR data being utilized for the project was obtained from the Data Acquisition Component of the UP DREAM/Phil-LiDAR 1 Program. The data delivered by this component have already been corrected for acquisition errors and processed to the standard LAS file format.

For areas without LiDAR coverage or had no available high-resolution satellite images, the project used freely downloadable Landsat satellite imagery from the U.S. Geological Survey (USGS) website. Landsat images are composed of multispectral image bands with 30m by 30m pixel resolution. The coastal features extracted from these images provide a good measure of the available resources for areas without high resolution LiDAR or satellite image data.

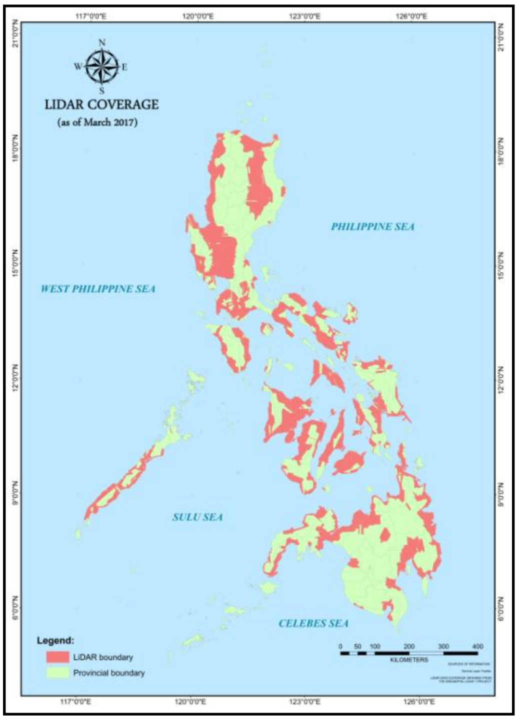

Figure 2. LiDAR Coverage in the Philippines

3.2. Processing

To extract aquaculture ponds and mangroves, an object-based image analysis (OBIA) was employed. Image layers such as digital surface model (DSM), digital terrain model (DTM), number of returns, canopy height model (CHM), slope, hillshade and intensity were derived from LiDAR point clouds. Available orthophotos were also added in the layers for OBIA along with the field data and other secondary references. The processing started with grouping the image pixels by segmentation based on spectral similarities and object's properties such as texture, context, and geometry. The image segmentation is a critical step as the objects segmented were used as basis for the classification. Assigning classes using threshold values of objects obtained from the derivatives was done to extract some of the classes. Similarly, Support Vector Machine (SVM) a type of supervised classification method was used for the extraction of the remaining classes needed. Two (2) different sets of points, training and validation, were used in the methodology. Training points were used in the SVM classification while the validation points were used to determine the accuracy of the classification. These set of points were gathered through the field and supplemented by satellite images. Lastly, an assessment was done to test how accurate the classification was.

3.3. Data Validation

The Project employed various methods of field data collection in order to produce detailed maps of the coastal resources. Field surveys are integral part of the mapping process as these provide supplementary datasets that aid classification and ensures accuracy of maps produced. Training data collection was done to gather reference data to be used in subsequent image classification while field validation was implemented to determine the accuracy of the classification results. The field techniques used in both types of survey include point observation using handheld GPS and underwater video tow.

A reconnaissance was conducted before the actual fieldwork to have an idea of the benthic feature locations. In the field, a stratified random sampling design was used in obtaining sampling points for training data collection. Using this method, a specific number of sample points in a predetermined category is assigned. Study sites were mapped out as well. The pre-selected points were pre-loaded in the handheld GPS. Underwater features are more difficult to identify compared to ground features. As such, assistance of locals and further research were needed in order to correctly identify the said features.

The sampling points were individually located and marked in the field. Pre-identified validation points were also located to compare the results of the classification with the actual ground feature. After point data collection, video tow was conducted to acquire continuous shots of the benthic features or features submerged in water. Data and other relevant observations were recorded in the field data sheets along with the data-gathering equipment. Proper planning and adherence to field techniques guidelines ensure efficient and effective field data collection.

Figure 3. Field techniques employed in the Phil-LiDAR 2 Project 2; sampling location for mangroves (upper left, lower right), aquaculture structures (upper right) and benthic habitats (lower left)

3.4. Capacity Building

Training programs were developed to upgrade knowledge and skills in geospatial technologies for mapping natural resources. Training on basic remote sensing and GIS was also provided to the project staff. Aside from the development of the standard coastal resources extraction methodologies, the Project was also able to introduce these workflows to the different State Universities and Colleges (SUCs) and the Higher Education Institutions (HEIs). The project members conducted trainings and demonstrations to the SUCs and HEIs on how to implement the algorithms and perform the data gathering techniques.

Figure 4. Training and mentoring sessions for the partner SUCs and HEIs

The University of the Philippines also conducted field visits to the partner universities at least twice a year to monitor their progress, present processing updates, and discuss other project implementation concerns.

4. RESULTS

Classification maps were generated after obtaining an acceptable accuracy assessment following the image classification procedures. The class shapefiles were exported in the GIS software to prepare the final classification maps that show the following coastal resources: mangroves, aquaculture structures (fish ponds, fish traps), and the benthic features like seagrass, corals, sand, rubbles, and rocks. Non-coastal features were also presented in the map for reference which include other vegetation covers and non-vegetation features such as buildings, bare soil, and water.

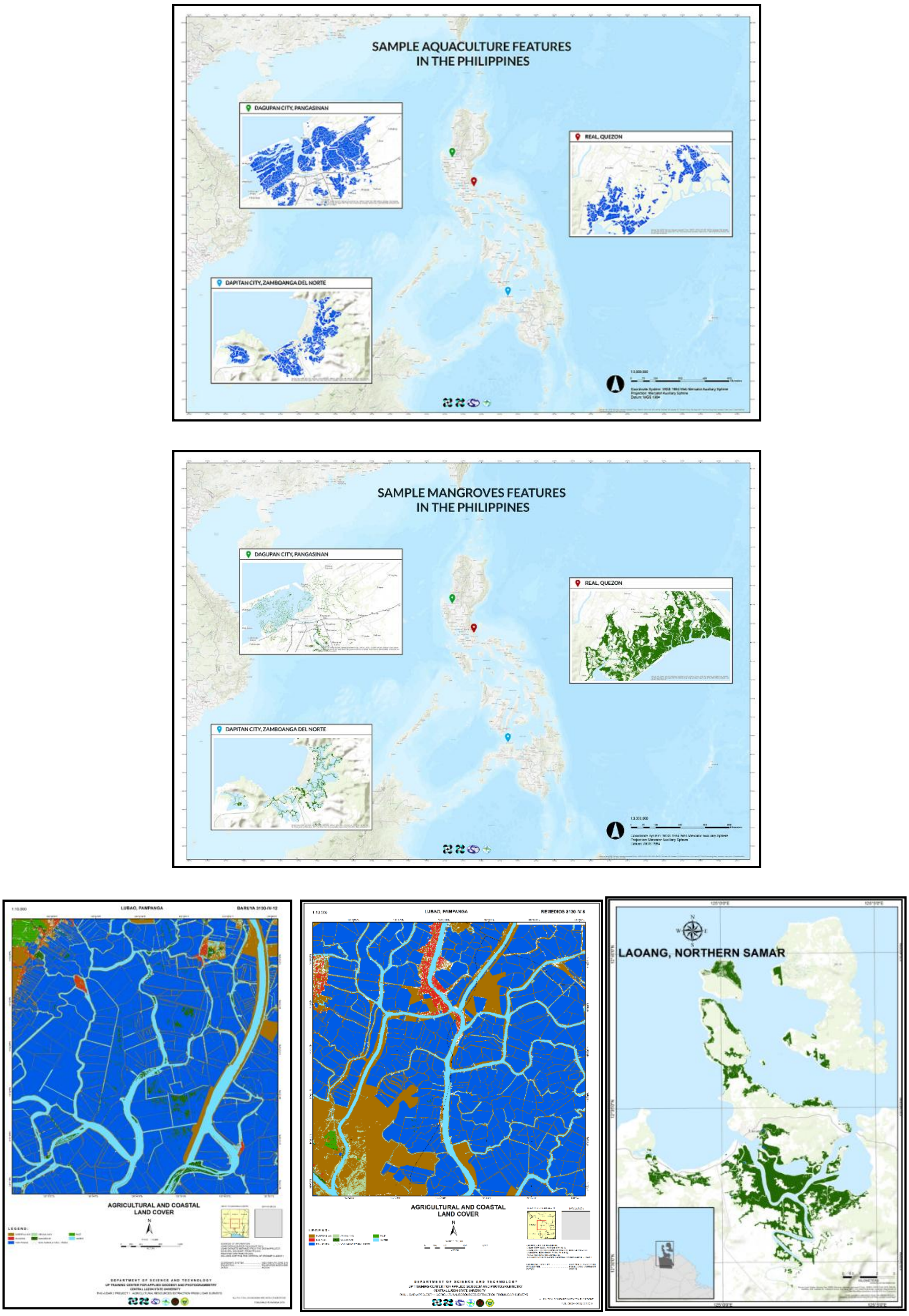

Figure 5. Sample Coastal Resource Maps using Remote Sensing Data

The project employed a quick deployment of maps to the local government units and national government agencies for their use in planning, resource monitoring and management. To further facilitate the distribution of maps, the partner SUCs and HEIs were tasked to turnover their products to their respective government units. They were required to conduct orientation and short GIS training courses for the stakeholders. These aimed to discuss to them the usage of maps, its limitations, and how to update the products.

Figure 6. Resource Maps Turnover to Government Units

5. CONCLUSION AND DISCUSSION

The Project, consisting of 15 universities, was able to produce maps of coastal resources from the available LiDAR data in the country. The produced resource maps are used not only to provide comprehensive spatial and land cover information but also to extract information like coastal areas vulnerable to impacts of climate change and anthropogenic disturbances. These resource vulnerability maps are very essential in identifying areas that need urgent decisions and to assess gaps. Thus, it strengthens existing environmental policies and programs, address the gaps and loopholes in management system and create strategic actions in addressing different issues in fisheries and coastal environment. With this type of information, the interplay between these factors to climate change impacts can be used to properly manage coastal areas.

The Project was also successful in human resource development and capacity building. Many young researchers and students who were part of the program were trained in remote sensing and geographic information systems. Similarly, the collaboration between government units and academic institutions was enhanced which could improve the natural resource management in the country.

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