MANGROVE EXTRACTION IN GLORIA, ORIENTAL MINDORO USING LIDAR

Precious R. Zara[1], Donald Luna[2], Davies Ocampo[3], Sarena Grace Quiñones[4], Charmina Sejalbo[5], Efren Rivera, Jr[6]., Damasa Magcale-Macandog[7]

[1]*University of the Philippines Los Baños (UPLB), Laguna, Philippines,* *preciouszara@gmail.com*

[2] *University of the Philippines Los Baños (UPLB), Laguna, Philippines,* *lunadonald@gmail.com*

[3] *University of the Philippines Los Baños (UPLB), Laguna, Philippines,* *daviesocampo@gmail.com*

[4] *University of the Philippines Los Baños (UPLB), Laguna, Philippines,* *shacequin@gmail.com*

[5] *University of the Philippines Los Baños (UPLB), Laguna, Philippines,* *cgsejalbo@up.edu.ph*

[6] *University of the Philippines Los Baños (UPLB), Laguna, Philippines,* *ecrivera@up.edu.ph*

[7] *University of the Philippines Los Baños (UPLB), Laguna, Philippines,* *dmmacandog@gmail.com*

Abstract: Determining the spatial location of mangroves is important in environmental management of coastal ecosystems. Mangroves serve as protection of shorelines from storms and waves. Various fauna thrive on mangroves; it serves as nursery for shrimps, crustaceans, mollusks and fishes. Through remote sensing and geographic information system, the environmental managers will be able to conduct a rapid and effective assessment that can be used as basis for habitat management plans. Light Detection and Ranging (LiDAR), a remote sensing technology that can examine the surface of the earth, has the capacity to produce high accuracy and high spatial resolution map. This study aims to determine the location of mangroves in Gloria using LiDAR and to propose a rehabilitation site for mangrove plantation in the area. There are histories of storm surge and strong typhoons in Gloria that affect several households in coastal zone. An additional layer of mangroves can serve as a protection for these threats and can lower the vulnerability of Gloria in such disasters. This study used support vector machine in extracting mangroves guided by field survey data. The produced map clearly shows areas that lack layers of mangroves; abandoned fishponds were also classified and these are the proposed priority areas for rehabilitation.

Keyword : LiDAR, Coastal ecosystem, Mangrove rehabilitation, Support vector machine, Classification

INTRODUCTION

Mangrove is a forest type that can be found along the tidal mudflats and shallow water in coastal areas. It extends in the inland along rivers and streams where there is brackish water (Melana et. al., 2000). According to Department of Environment and Natural Resources (DENR), mangrove forest is also known as the rainforest of the sea and grown in tropical countries such as the Philippines. It is vital in the marine and coastal ecosystem. In the Philippines, around 46 species out of the 70 mangroves species around the world can be found in different parts of the country. In 1918, the mangrove forest in the country is estimated to be as much as 400,000-500,000 ha (Brown and Fischer, 1918). However, due to direct and indirect threats to mangroves, it has continually decreased through the years. As of 2000, the estimated remaining area of mangroves is 130,000 ha (Aizpuru et. al., 2000).

Mangroves serve as home to many biodiversity and it plays a big role in linking marine and terrestrial ecosystems. These areas offer nursery grounds for juvenile fish, crabs, shrimps and mollusks. Several species of birds also use mangroves as nesting and migratory sites. In addition to that, mangrove wetlands serve as home to manatees, monkeys, fishing cats, monitor lizards, sea turtles and mud-skipper fish. Aside from providing home to different marine and terrestrial ecosystems, mangroves also provide protection for the coastal areas. Mangroves protect coastal areas from destruction due to storms, reduction of shoreline and riverbanks erosion by stabilizing sediments as well as absorbing pollutants in coastal zones. The economic value estimated for mangrove wood and fish products in the country ranges from $150 to $1396 per hectare per year (White and Trinidad, 1998 as cited by Dieta and Arboleda, 2004). These fishery products include fishes, shells, shrimps, crabs and crustaceans. Aside from the economic benefits that the mangrove forest can provide, it can also give ecological benefits such as source of products like medicine, alcohol, charcoal, tannin, timber and other housing materials; support in aquaculture and fisheries; provide shelter and food for fish and other sea creature; protect coastal communities from storm surges, tides, waves and currents; reduce organic pollution along the coastline; and stabilize coastline through erosion reduction (DENR website).

Yet, in spite of these various benefits that can be generated from a productive mangrove ecosystem, the world’s mangrove resource at present continue to reduce considerably due to a number of reasons (Field, 1999). In the Southeast Asia, such significant reduction of mangrove forests has been accounted to the following key factors: population pressure, wood extraction, conversion to agriculture and salt production, tin mining, coastal industrialization and urbanization, and conversion to coastal aquaculture (Ong, 1995; Macintosh, 1996). In addition to these anthropogenic factors are natural causes such as the existence of storm surge and strong typhoons in the region. This is specifically experienced in the Philippines where 20 typhoons, on the average, enter its area of responsibility every year (Romualdez et al., 2011). The combination of these factors threatens our mangrove ecosystems at present and, thereby, prompted a massive mangrove forest rehabilitation efforts and movements around the world.

In the recent years, mangrove ecosystem rehabilitation is motivated by three major objectives. These include conservation of a natural system and landscape, sustainable production of natural resources and protection of coastal areas (Field, 1999). In the Philippines, however, coastal protection is undeniably one of the most important mangrove functions. Such specific importance of mangroves in the country also became the primary driving force of various groups, both local and international, to rehabilitate mangroves (FAO, 2005). Numerous mangrove planting programs and initiatives have been pursued in the country, ranging from community initiatives (1930s–1950s) to government-sponsored projects (1970s) to large-scale international development assistance programs (1980s to present). However, most of these rehabilitation projects, specifically 80%-90%, have been assessed to be poor in terms of their survival rate. Such low project survival rate was mainly attributed to two factors: inappropriate species and unsuitability of the sites selected (Primavera and Esteban, 2008).

This, then, highlighted the purpose of this paper. This study intended to locate potential areas for mangrove plantation and rehabilitation in the locality of Gloria, Oriental Mindoro to protect its coastal area and in turn reduce its vulnerability to the destructive effects brought about by natural disasters.

Traditional methods in mapping agricultural and coastal resources are costly, difficult to conduct and only cover small area (Tuhldahll and Wikstrom, 2012). Therefore, a new technology must be used to improve the mapping of this resources. This is where remote sensing become helpful. Remote sensing can be easily defined as a technique of collecting data about an object from measurements made at a distance from the object (Dahdouh-Guebas, 2001). Remote sensing, compared to the traditional methods, has better spatial coverage. It can map large range of agricultural and coastal areas in a short time scale at a lower scale. It is an alternative method in detecting features of tree canopy and crops. Moreover, it can cover remote areas like densely forested areas, riparian zones and steep sloping agricultural landscapes (Johansen et al., 2007). Some remote sensing techniques being utilized are satellite imagery, aerial photographs and ocean bathymetry through radar. Another remote sensing technique being widely used is Light Detection and Ranging or LiDAR technology. LiDAR is one of the remote sensing techniques which provides more accurate measurements. It makes use of pulse of light energy which is emitted and the precise time is recorded. The energy which was emitted will be reflected by a ground feature and precise time is recorded. Having known of the speed of light, the range between the source and the ground feature can be determined (Denney, n,d.). It is also cheaper than the other high resolution remote sensing products which cover large spatial extents. LiDAR provides spatial data that could be used in applications such as hazard assessments, urban development, flood modelling, storm water management, hydraulic engineering, infrastructure planning/development, natural resource management, environmental studies, obstruction analysis, transportation engineering, and site design engineering among others. Moreover, it provides precise and accurate elevation, and surface models. The LiDAR data can also be used in updating topographic data (Johansen et al., 2010). The LiDAR application has spanned from different fields that require identification and accurate recording of landscape features (Barber et al., 2016). Several researches today have continuously shown the utility of LiDAR data for research and management purposes.

On the other hand, Geographic Information System (GIS) is a tool for handling and interpreting geospatial data as well as remotely-sensed data. GIS can provide spatial characteristics of an area through different digital layers which can be derived from the acquired data (Dahdouh-Guebas, 2001). The pieces of information from the data is complemented with ground-truth data to assure the reliability of data gathered. Together, remote sensing and GIS can be helpful also in coastal resource management. Managers can refer to spatial data in providing effective laws in protection and conservation of coastal resources. Data can be used in (a) environmental monitoring; (b) resource inventory and mapping; (c) damage assessment; (d) protected area management and (e) coastal hazards (NASA, 1997).

The Department of Science and Technology Grants-In-Aid (DOST-GIA) sought to address the destructions caused by disasters in the country by designing mitigation measures through the use of the LiDAR technology. In this light, the project entitled "*Project 4. LiDAR Data Processing, Modeling and Validation by HEIs for Detailed Resources Assessment in Luzon: MIMAROPA and*

Laguna (Region IV)" under the program '*Phil-LiDAR 2. Nationwide Detailed Resources Assessing using LiDAR-Program B. LiDAR Data Processing and Validation by SUCs and HEIs'* is implemented to help in providing detailed information needed by government agencies and local government units for better planning and decision making. The research project generally aims to produce detailed resource maps using LiDAR-derived data for five components namely: Agriculture, Coast, Forest, Renewable energy, and Hydrology. Specifically, it aims to (a) automate feature extraction from LiDAR data and various types of remotely-sensed data; (b) produce high resolution maps for high value crops (HVCs), renewable energy sources, irrigation and hydrology, coastal resources and forest resources; (c) assess vulnerability of HVCs and aquatic resources to climate change; and (d) formulate recommendations on the inventory and vulnerability assessment of the above said resources. The project is currently using the following processing software: ArcMap; ENVI 5; eCognition Definiens; and LASTools. The expected outputs of the project include validated accuracy of LiDAR collected data; algorithm that will delineate, extract and quantify objects to detect HVCs and coastal resource features from LiDAR data sets and/or orthophotos; features salient to HVC and aquatic production; detailed resource maps for MIMAROPA region and Laguna; vulnerability assessment maps of HVC and aquatic resources to climate change; policy papers; and scientific papers for publications and presentation in conferences.

SITE DESCRIPTION

Gloria is part of Oriental Mindoro, located 76 kilometers from Calapan, the capital town of the province. It is bounded by the municipality of Pinamalayan on the North, municipality of Bansud on the South. It has a total land area of 28,029 hectares and has 27 barangays (Figure 1), among these barangays, nine are coastal namely: Bulaklakan, Tambong, Kawit, San Antonio, Balete, Sta. Theresa, Giumbonan, Maragooc, and Agsalin. Gloria is rich in marine and coastal habitats that host various species of fishes. It has coastal resources such as mangroves, fishponds, corals, and sea grasses. It has marine protected areas: Agsalin Fish Sanctuary, Tambong Fishery Reserve, and Sta. Theresa Fish Sanctuary.

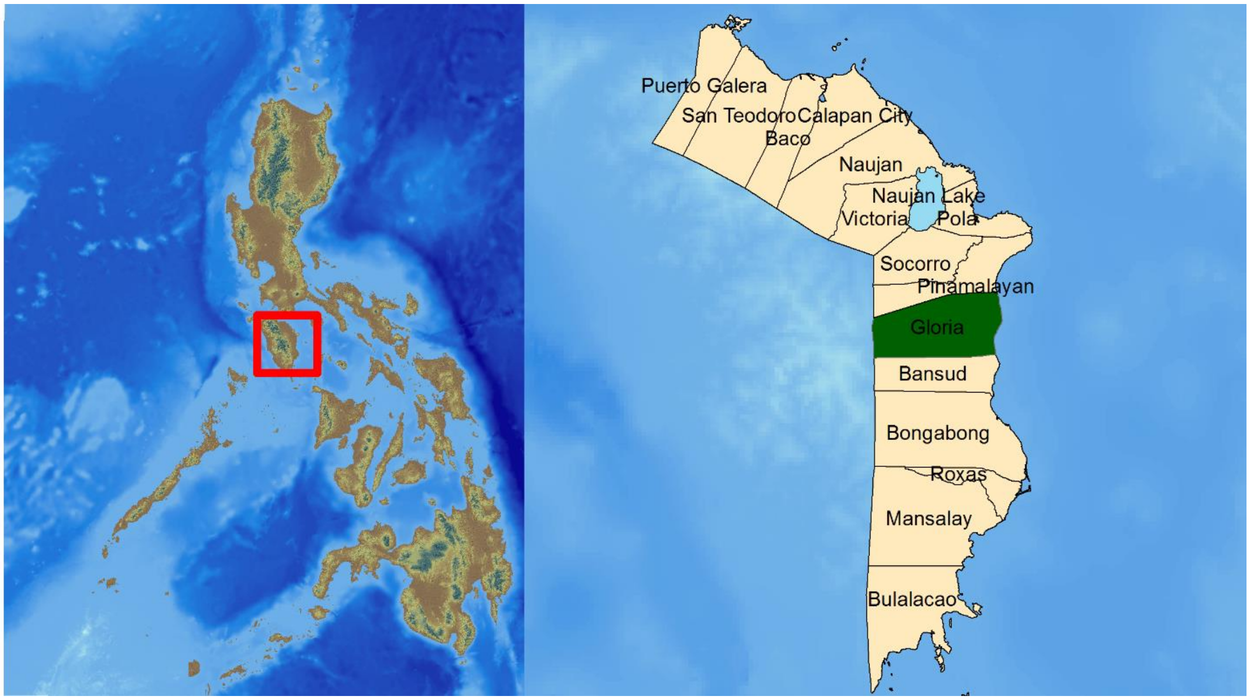

Figure 1 Location map of Gloria, Oriental Mindoro

MATERIALS AND METHODS

Materials

There are five blocks of LiDAR dataset in Gloria: B, BS, BS add, C unpro, and D with a total area of 57.56 km^2. Ten layers of LiDAR derivatives were used in this study.

Digital Surface Model. This layer depicts elevations of the top of the reflective surfaces like built-up and vegetative areas.

Digital Terrain Model. This layer is a digital representation of bare Earth meaning all the elevated top of surfaces are not shown which gives only topographic surfaces.

Canopy Height Model. This is a digital representation of tree canopies.

Hillshade. This layer is the same as the digital surface model but this simulates the effect of sun's rays over the varied terrain of the land.

Intensity. This layer shows the variation in the strength of the LiDAR returns with the composition of the surface object reflecting the return.

Normalized Height (nDSM). The layer is produced by obtaining the difference between the digital surface model and digital terrain model.

nDSM=DSM-DTM

Number of Returns. This layer shows the multiple hits of laser pulses especially in the vegetated and forest areas where LiDAR data was collected.

Slope. This layer is a digital representation of the incline or steepness of a surface.

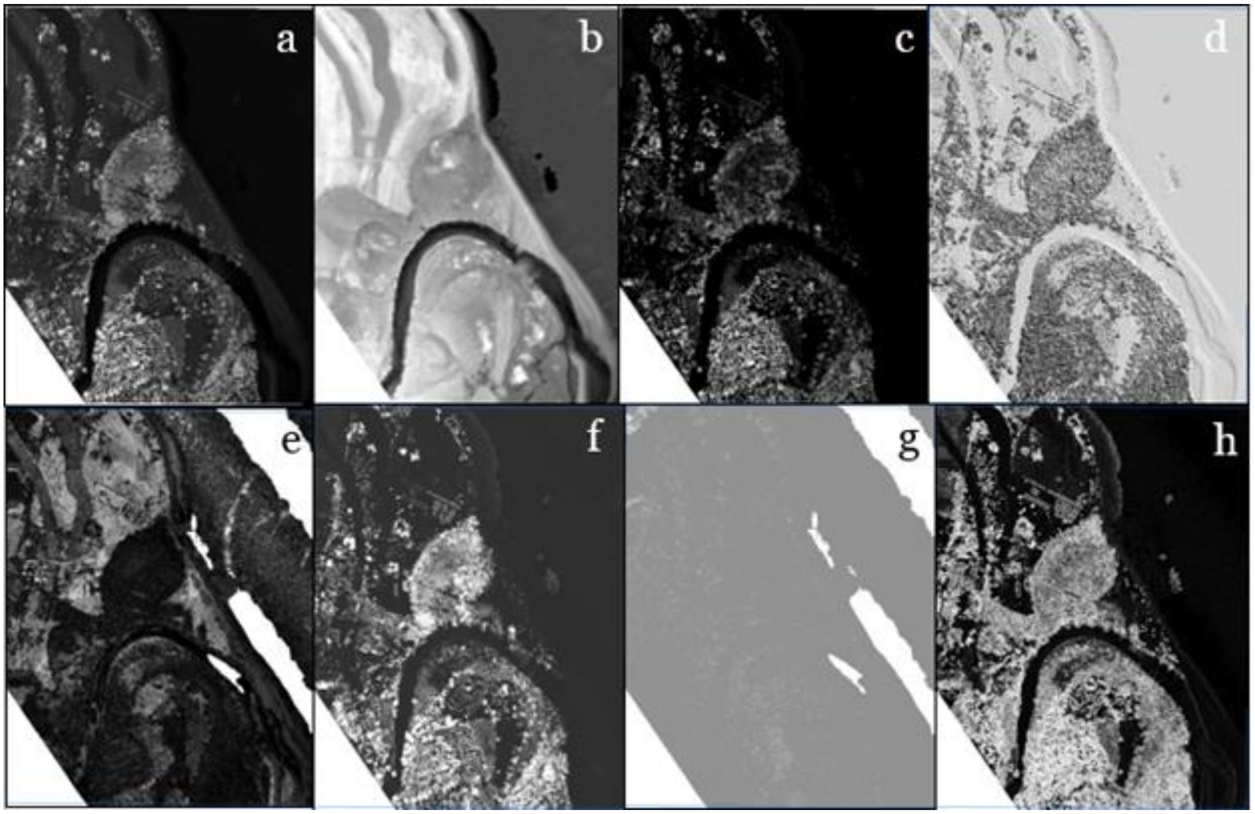

Figure 2 LiDAR Derivatives (a) DSM; (b) DTM; (c) CHM; (d) hillshade; (e) intensity; (f) nDSM; (g) number of returns; (h) slope

Methods

Part of the initial step needed for object-based image classification is the breaking down of the image into objects through Segmentation. The segmentation algorithm is usually implemented in two ways namely the Multi-threshold and Multiresolution. Multi-threshold segmentation is the splitting of an image into objects in reference to a threshold value as compared to the individual pixel value of the image cells. Multi-threshold segmentation is particularly useful in preliminary separation of image into major object groups and in refinements for later stages of the project.

The threshold values used in the algorithm are user-defined and frequently determined by exploring the topography and vegetation the image represents. This implies that most of the threshold values are data specific. However, a trend can always be made in reference with previous image classification works to make the establishment of these values more efficient. Size of the resulting objects that will represent the original image depends on the minimum object size and the threshold value used. Multiresolution segmentation, on the other hand, is a more powerful tool since it looks into more detail than what multi-threshold does but technically they are similar algorithms. What makes this possible is the increase in number of parameters considered during the grouping of pixels into objects. As a result, an increase of objects to represent a greater number of class can be observed. This enables implementation of object-based image classification at a higher resolution. Once segmentation is completed, image classification will then be carried out. Image classification is the meaningful grouping of objects (group of pixels) into classes based on certain criteria. The criteria is grounded on the characteristics that can be extracted on the LiDAR derivatives. Using the LiDAR derivatives, the first step in mangrove extraction is the separation of areas with data and areas with no data. For block B, areas with CHM less than or equal to -0.9999 were considered as no data while areas greater than -0.9999 were considered as objects with data. Objects with data were then separated into water and land using DSM layer. Areas with mean DSM of equal and less than 52 were considered as water while areas greater than 52 were classified as land. Water class is further classified to separate fishpond in the area using relative border and multi-threshold using intensity layer. The thresholds used were based on visual inspection of different LIDAR derivatives. Fishpond class was post-processed in ArcGIS for smoothening and refinement. Abandoned fishponds were identified and validated by conducting field survey and key informant interviews to LGU. Land class was divided into ground and non-ground features using values for mean NDSM. Land areas with mean NDSM of less than 1 is classified as ground class. These are features like rice fields, grasslands and bare land. Land areas with mean NDSM equal and greater than 1 is classified as non-ground class. To further classify non-ground feature to mangrove, other vegetation and non-vegetation, support vector machine (SVM) was used. SVM is a powerful algorithm to do the job. SVM separates objects into classes by finding an optimum combination of thresholds in a set of characteristics selected. These characteristics or properties can either be layer values, geometry, and position among others. Training and validation points were collected through visual inspection in LiDAR derivatives and field validation using simple random sampling. The distribution of training and validation were monitored during the creation of points. Three classes were then determined namely mangroves, other vegetation and non-vegetation. Points were collected from non-ground class. Accuracy assessment is carried out after the image classification to verify the validity of the results. A reference layer of field validation points is overlaid to the results of SVM to analyze the agreement of the image classification result to the field condition.

RESULTS AND DISCUSSIONS

Mangrove and fishpond are extracted after getting an acceptable accuracy in the classified map. Figure 3 shows the extent of mangroves and fishponds in the area. Table 1 summarizes the area of mangroves in each barangay.

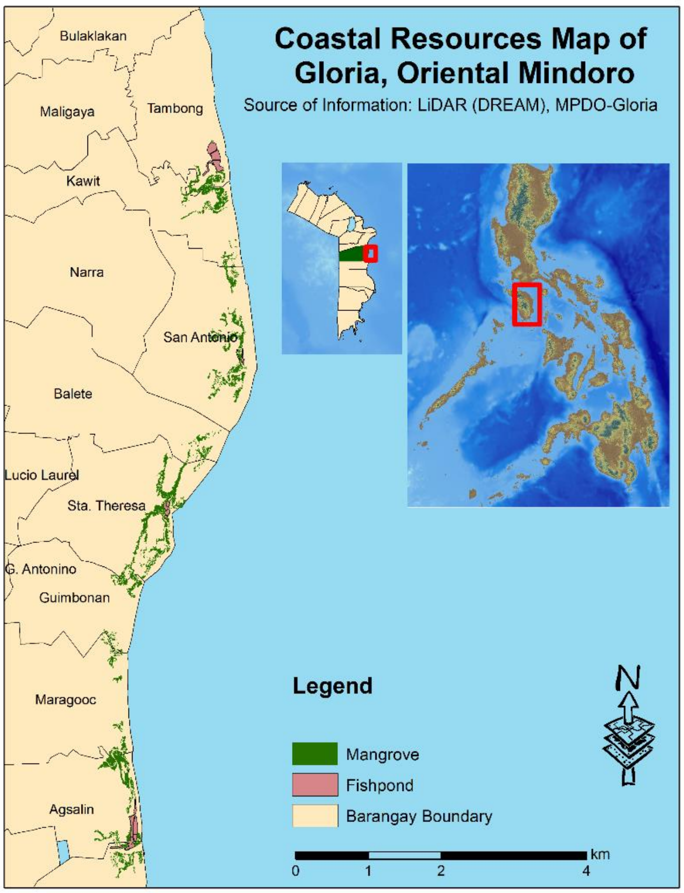

Figure 3 Map showing the extent of coastal resources in Gloria

Table 1 Summary of mangrove area in each barangay

Barangay	Area (km^2)
Agsalin	0.13
Balete	0.03
Guimbonan	0.04

Kawit	0.08
Maragooc	0.05
San Antonio	0.15
Sta. Theresa	0.19
Tambong	0.05
TOTAL Area	0.73

The coastline is not fully covered with mangroves; immediately after the shore are aroma (*Acacia farnesiana)* shrub. Mangroves in Gloria has a total land area of 0.73 km^2. Barangay Sta. Theresa has the largest area of mangroves with 0.19 km^2 while Barangay Balete has the least with 0.03 km^2. The mangroves in Sta. Theresa is the only remaining old growth forest in the municipality. With the help LGU, there are mangrove planting programs in the municipality that can contribute to the additional protection against strong waves and storm surges. However, the whole province of Oriental Mindoro was badly hit during the typhoon Nona last December 16, 2015. Damages and decline of area in crops, beach forest species, and mangroves does not reflect here on the map, because the acquisition of LiDAR data was on March 2015 (verify).

Table 2 summarizes the area of fishpond for each barangay. There are 0.1131 km^2 total area of fishpond in the municipality, barangay Tambong has the largest area of fishpond while barangay Guimbonan has the least fishpond in terms of area. There are no fishpond present in barangay Bulaklakan, Tambong, Kawit, Balete, and Maragooc. According to the municipal agriculture office, fishponds in barangay Agsalin are abandoned. This barangay is given priority for rehabilitation efforts of the LGU.

Table 2 Summary of area of fishpond in Gloria

Barangay	Area (km^2)
Agsalin	0.0470
Guimbonan	0.0007
San Antonio	0.0058
Sta. Theresa	0.0118
Tambong	0.0478
TOTAL Area	0.1131

Accuracy assessment reports of the five blocks is summarized in Table 3. All blocks have an above 90% total accuracy and KIA. Having a mean of 0.9766 in Overall accuracy and 0.9617 in KIA, the classified map is a high accuracy large scale map.

Table 3 Accuracy assessment report of the five blocks

Block	Overall Accuracy	KIA
B	0.9688	0.9470
BS	0.9683	0.9476
BS add	0.9990	0.9980
C unpro	0.9738	0.9589
D	0.9731	0.9568
Mean	0.9766	0.9617

CONCLUSIONS AND RECOMMENDATIONS

The coastal area of Gloria is covered with beach forest species such as mangrove (*Rhizophora sp., Avicennia sp.)*, aroma (*Acacia farnesiana)*, and nipa (*Nypa fruticans)* that makes an additional layer of protection in the coastal communities from strong waves and storm surge. Through the produced map, users can determine effectively and efficiently possible areas for further rehabilitation and reforestation of mangroves. There are barangays in Gloria that lack layers of mangrove, LGU can focus on these areas for future rehabilitation practices. These are barangay Bulaklakan, Balete, Guimbonan, Maragooc, and Tambong. Abandoned fishponds in barangay Tambong are the best place of rehabilitation and growth of propagules and/or wildlings of mangroves as Primavera (2012) stated that abandoned fishponds are the best. The map can also be used as an input to the coastal management plan, baseline studies, and comprehensive land use plans.

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