USING LIDAR FOR EXTRACTING ABANDONED BRACKISH WATER FISHPOND FOR MANGROVE REVERSION SUITABILITY ANALYSIS

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ABSTRACT: Mangroves have been targets of fishpond conversion for the past 50 years. With the need to increase sources of food and increase productivity of aquaculture, a considerable mass of mangroves in the Philippines and in other parts of the world have been converted into brackish water ponds. To prevent from further harming our mangrove forests, many mangrove management, protection, and preservation efforts have already been done. This study aims to help in the identification of abandoned brackish water ponds for mangrove reversion using LiDAR data. In order to extract them from LiDAR data the Digital Surface Model (DSM), Digital Terrain Model (DTM), Canopy Height Model (CHM), Number of Returns, and Intensity were derived from the LiDAR data. Rugosity, slope, and slope of slope were then derived from the DSM. Furthermore, Principal Component Analysis (PCA) was applied to DSM, slope of slope and rugosity. The fishponds were classified using Object Based Image Analysis. Higher segmentation weights were given to the PCA and slope derivatives since they contain clear delineation between dikes and fishponds. The process resulted into an initial classification of fishponds, followed by further classification of which are abandoned and which are not. The fishponds were checked for rectangular fit and shape attributes since most abandoned fishponds that are extracted in LiDAR data do not have a defined quadrilateral shape. Furthermore, mean slope of slope was used to check for more vegetated fish ponds since fishponds with tall vegetative structures inside them would have higher mean elevation values. A Euclidean distance process was also applied on the mangroves in the area in order to check which of the extracted abandoned fishpond is the nearest to existing clustered mangroves. The location where there are extracted abandoned fishponds may be considered as candidates for mangrove reversion.

1. INTRODUCTION

Aquaculture is a very significant sector in the Philippines' fisheries scene and the most dynamic ever since the deterioration of fish yield from marine fisheries starting 1976 (Aypa, 1995). The Philippines' 0.815 million metric tons aquaculture production of fish, crustaceans and mollusks in 2013 ranked 11th in the world and a 1.16% share to the total global aquaculture production of 70.2 million metric tons (DA-BFAR, 2014). The overall value of the country's aquaculture production of fish, crustaceans and mollusks has amounted to over 1.98 billion dollars (DA-BFAR, 2014). As compared to marine fisheries, aquaculture is a more manageable and controllable system of fish production (Aypa, 1995).

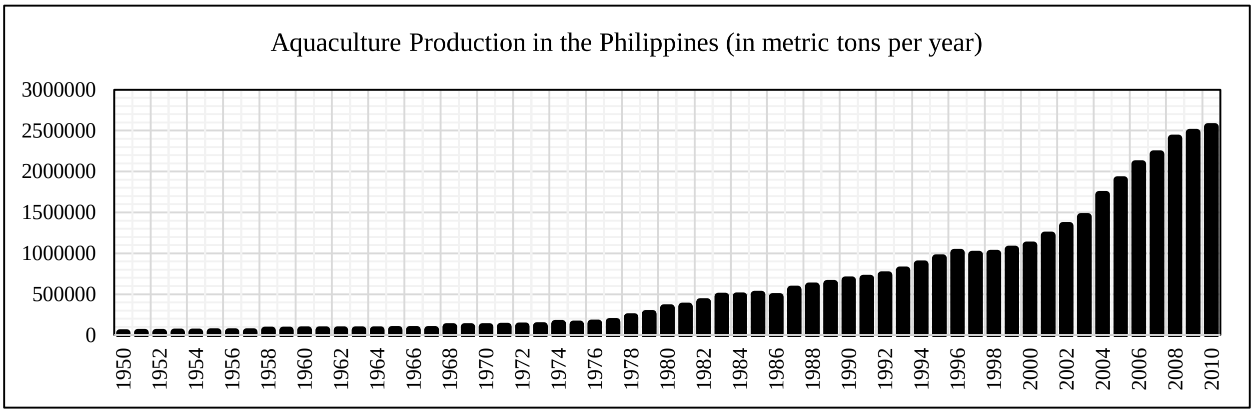

Figure 1. Aquaculture Production in the Philippines (FAO, 2016)

With the decline of marine fisheries, and the rise in fishpond aquaculture, some of our mangrove forests have been converted into fishponds. Although there are legal methods in converting mangrove forests into fishponds aiming at protecting and avoiding exhaustion of our coastal resources, mangrove forest cover in the Philippines has still declined substantially during the last century (Brown and Fischer 1918; DENR 1988 as cited by White, 2004). From an estimated 450,000 ha of mangroves in 1918, less than 140,000 ha exist. At present, 95% of the remaining mangroves are secondary growth and only 5% are old or primary mangroves that are mostly found in Palawan (White, 2004).

Under section 43 of presidential decree no. 707 s. 1975 also knows as the Forestry Reform Code of the Philippines, Strips of mangrove forest bordering numerous islands which protect the shoreline, the shoreline roads, and even coastal communities from the destructive force of the sea during high winds and typhoons, shall be maintained and shall not be alienated. Such strips must be kept free from artificial obstruction so that flood water will flow unimpeded to the sea to avoid flooding or inundation of cultivated areas in the upstream. All mangrove swamps set aside for coast-protection purposes shall not be subject to clear-cutting operation. Mangrove and other swamps released to the Bureau of Fisheries and Aquatic Resources for fishpond purposes which are not utilized, or which have been abandoned for five years from the date of such release shall revert to the category of forest land. Unfortunately, these laws aren't adequate enough to protect out mangrove forests.

Figure 2. Results of Seafront Mangrove Planting Efforts in Barotac Viejo, Iloilo, Philippines

Figure 3. Few *Nypa fruticans* left after area was converted to a fishpond in Pontevedra, Capiz, Philippines

Primavera, Rollon & Samson (2011) recommends the rehabilitation of mangrove forests in the country by employing two key strategies: seafront planting and pond reversion. Compared to seafront planting, regeneration of abandoned ponds (located in the mid–upper intertidal levels), which mainly requires restoring hydrology and natural or assisted mangrove recruitment, has greater potential for restoring wide areas of mangroves, including species diversity (Primavera, Rollon & Samson, 2011). Primavera et al. (2013) assures us that pond reversion to mangroves will not compromise the country's food security but instead, it will bring back coastal protection, fisheries catches and other ecosystem services valued at $14,000-16,000/ha. Pond reversion to mangroves can be done by finding for abandoned brackish water ponds or by reviewing the fishpond lease agreement (Primavera, Rollon & Samson, 2011).

Aside from enforcing the law, site selection analysis for possible areas of reversion through geographic information systems can help a lot in restoring our mangrove forests. According to Primavera et al. (2013), the 4:1 mangrove-pond ratio required for environmental sustainability can be achieved by either seafront planting or reversion of abandoned ponds. Although seafront planting is very popular due to open access of beaches, it unfortunately has high mortality rates because of wave action and an added factor is the lowered elevation which is no longer suitable for mangrove survival due to scouring of the substrate with the loss of fringing mangroves (Primavera et al., 2013). Therefore Primavera et al. (2013) concludes that it is pond reversion which will give back mangroves in the thousands of hectares needed for the 4:1 ratio.

Figure 4. Abandoned Ponds in Victorias City, Negros Occidental, Philippines

Figure 5. Highly Vegetated Ponds in Victorias City, Negros Occidental, Philippines

2. MATERIALS AND METHODS

2.1 Workflow

The study used LiDAR derivatives such as Intensity, Canopy Height Model, Number of Returns, Digital Terrain Model, and Digital Surface Model and other rasters such as Slope of Slope were also generated using ArcMap. These rasters were then used as layers for the image processing. The figure below shows the workflow of the project.

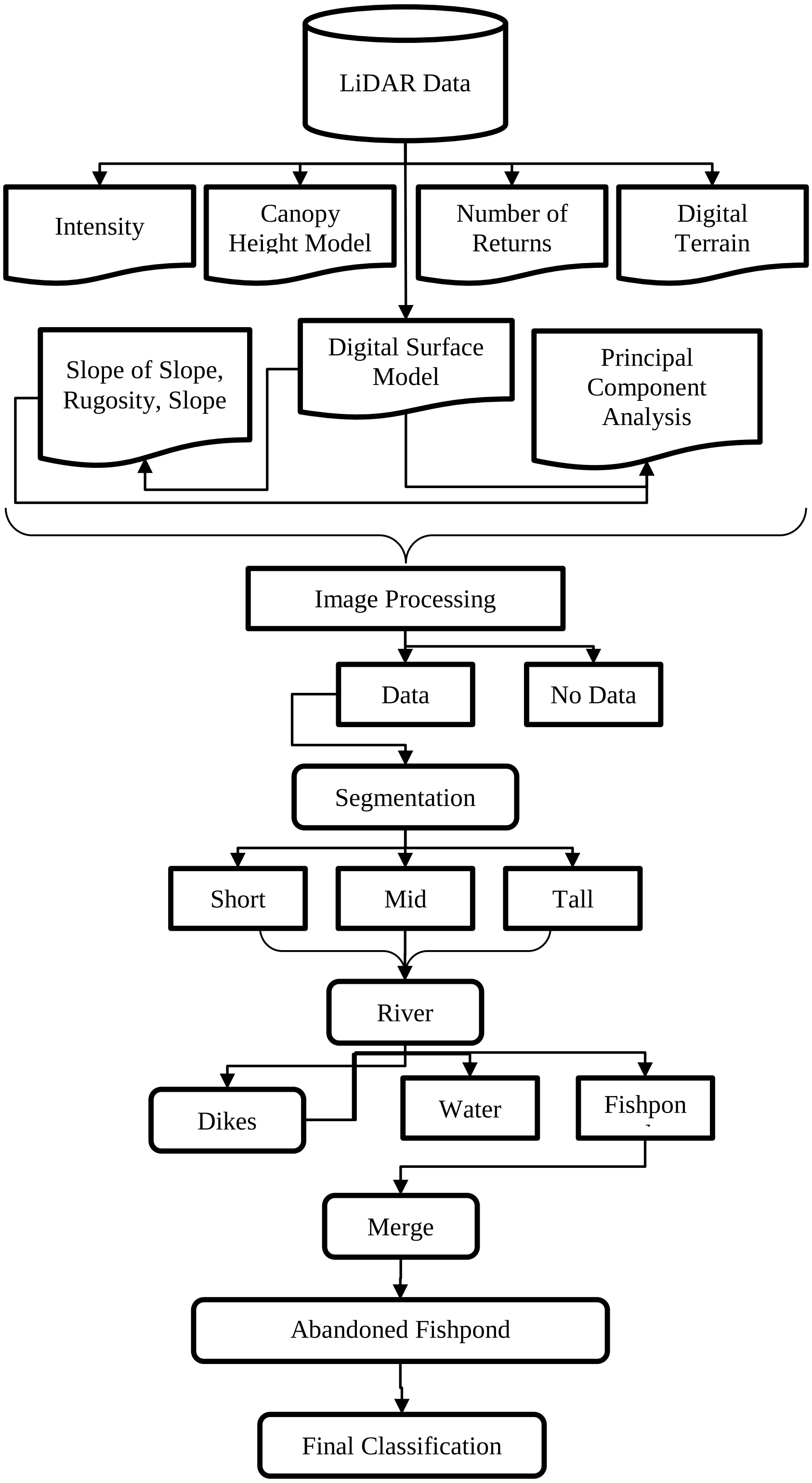

Figure 6. Workflow for extracting abandoned brackish water fishpond for mangrove reversion.

2.2 Data Pre-processing

The LiDAR data was pre-processed by the UP Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) which has been conducting a research entitled "Nationwide Disaster Risk and Exposure Assessment for Mitigation" (DREAM) supported by the Department of Science and Technology (DOST) Grants-in-Aid Program wherein the Data Processing Component (DPC) of the DREAM Program produces digital elevation models from the aerial LiDAR surveys conducted by the Data Acquisition Component (DAC) over the assigned areas (UP-TCAGP, 2013).

2.3 Study Site

The study was conducted in a small coastal city in the province of Negros Occidental in the Philippines. Victorias City has an area of 103.55 km.^{2} and a coastal line of approximately 9,453 meters.

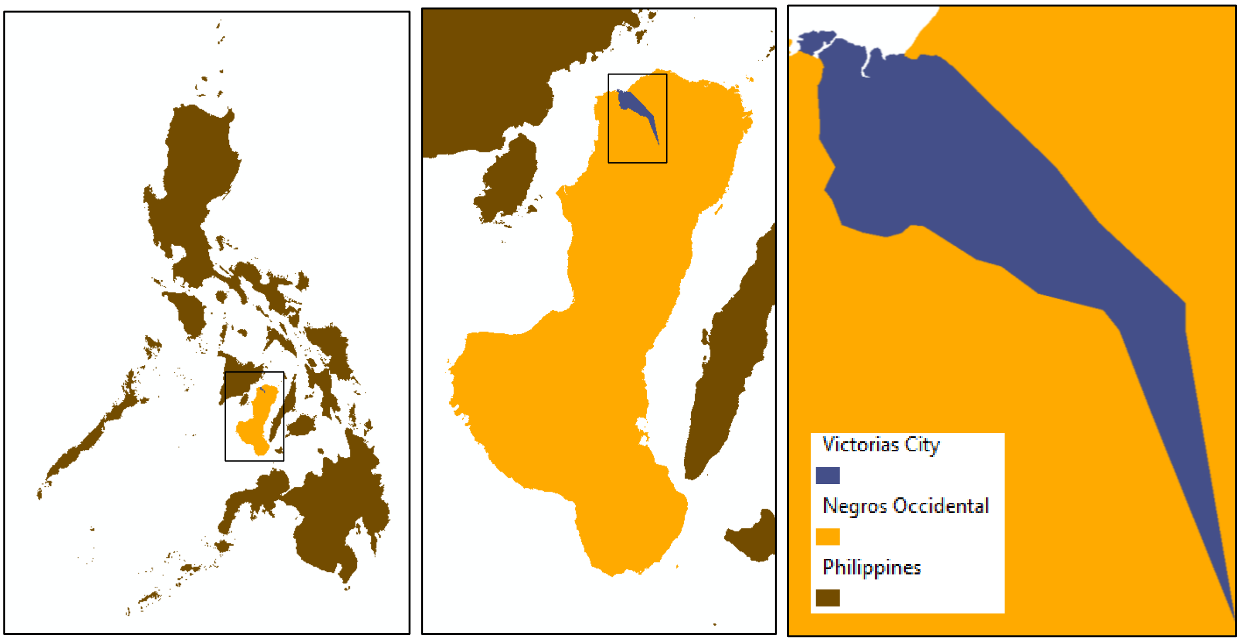

Figure 7. Victorias City in Negros Island as the Study Site

Victorias City was chosen as the study site because it has a very rich mangrove cover with a total of 2.71 km.^{2}. It also has a lot of fishponds present approximately 441 individual ponds covering a total area of approximately 3.29 km.^{2}.

Figure 8. Mangrove and Fishpond cover of a subset of the coastal are of Victorias City.

2.4 Layers Used

The LiDAR derivatives that were used in the study can be divided into two: derived from the las files and the others derived from the rasters derived from the las files.

2.4.1 LiDAR Derivatives: The lidar derivatives generated from the las files were Digital Surface Model, Digital Terrain Model, Canopy Height Model, Intensity, and Number of Returns. The images below are subsets of the aforementioned layers.

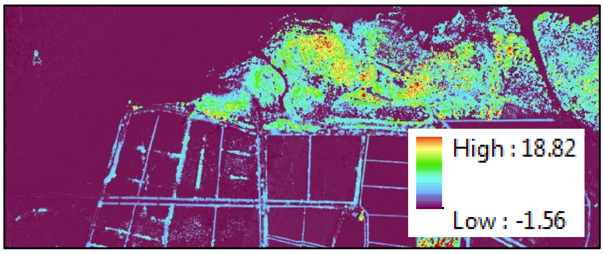

Figure 9. Canopy Height Model

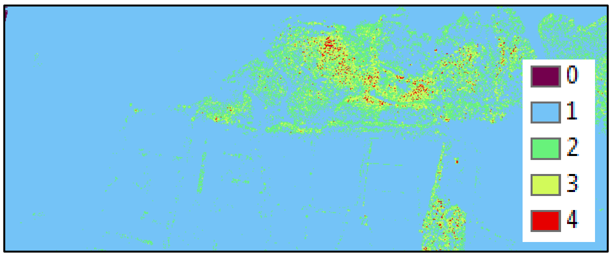

Figure 10. Number of Returns

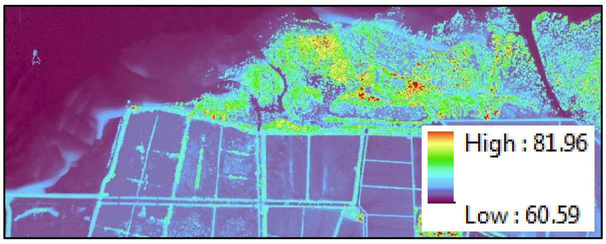

Figure 11. Digital Surface Model

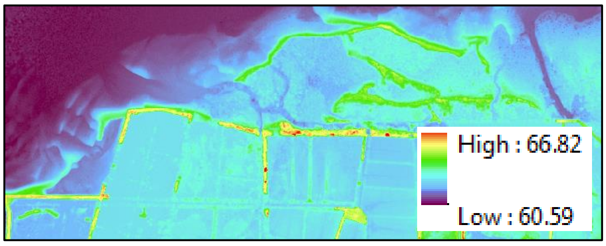

Figure 12. Digital Terrain Model

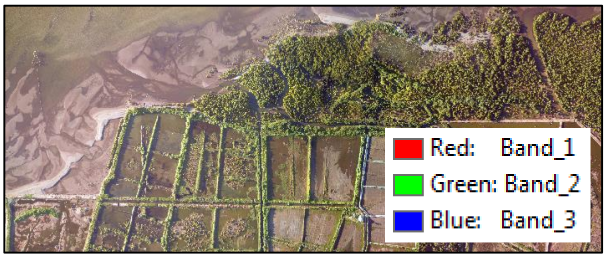

Figure 13. Orthophoto

Figure 14. Intensity

2.4.2 Rugosity: Rugosity is a measure of surface roughness and is the ratio of surface area to planar area. According to Jenness (as cited by UP-TCAGP, 2014) in his DEM Surface Tools manual, the surface area can be computed as follows:

$$Surface\ Area = \frac{Cell\ Size^2}{Cos(\,Slope * \frac{\pi}{180})} \tag{1}$$

The rugosity derivative was calculated using Raster Calculator (Spatial Analyst) in ArcMAP. The raster calculator Builds and executes a single Map Algebra expression using Python syntax in a calculator-like interface (ESRI, 2014). The resulting image can be seen below.

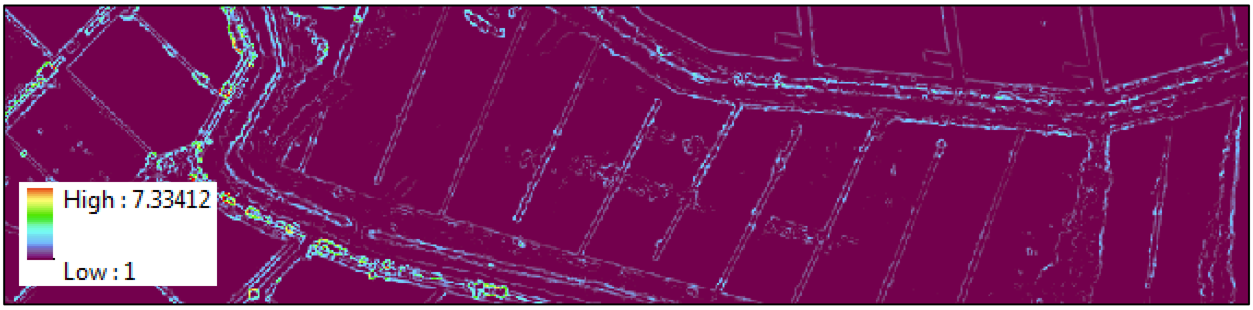

Figure 15. Rugosity

2.4.3 Slope of Slope: The Slope of Slope which is in units of degrees of degrees is a second derivative of the bathymetric height (UP-TCAGP, 2014). The Slope (3D Analyst) in ArcMAP identifies the slope (gradient, or rate of maximum change in z-value) from each cell of a raster surface (ESRI, 2012). It calculates the slope of a raster by using its immediate neighborhood or a 3 x 3 window surrounding each cell. Using the Slope (3D Analyst) function in ArcMAP, a slope derivative of the Digital Surface Model was created. After having the output, another derivative was created using the same method but instead of using the DSM as an input for the Slope function in ArcMAP, the previously processed slope was used instead. The resulting derivative is the slope of slope.

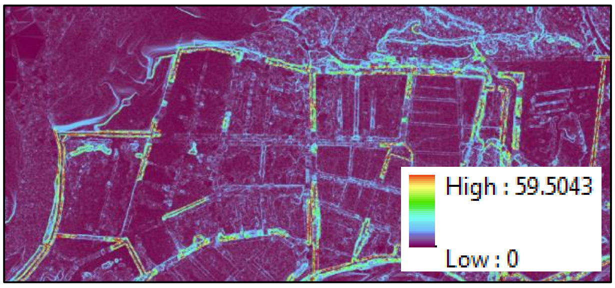

Figure 16. Slope

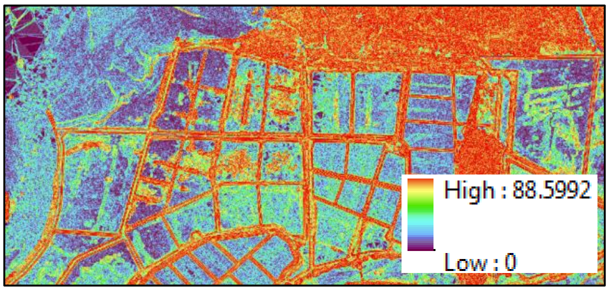

Figure 17. Slope of Slope

2.4.4 Principal Component Analysis: Principal Component Analysis (PCA) is a mathematical method which reduces the dimensionality of the original dataset by removing redundant information across the different bands (UP-TCAGP, 2014). The Digital Surface Mode, Slope of Slope and Rugosity derivatives were used as input for the Principal Components (Spatial Analyst) in ArcMAP. The said ArcMAP functionality performs Principal Component Analysis (PCA) on a set of raster bands and generates a single multiband raster as output (ESRI, 2012).

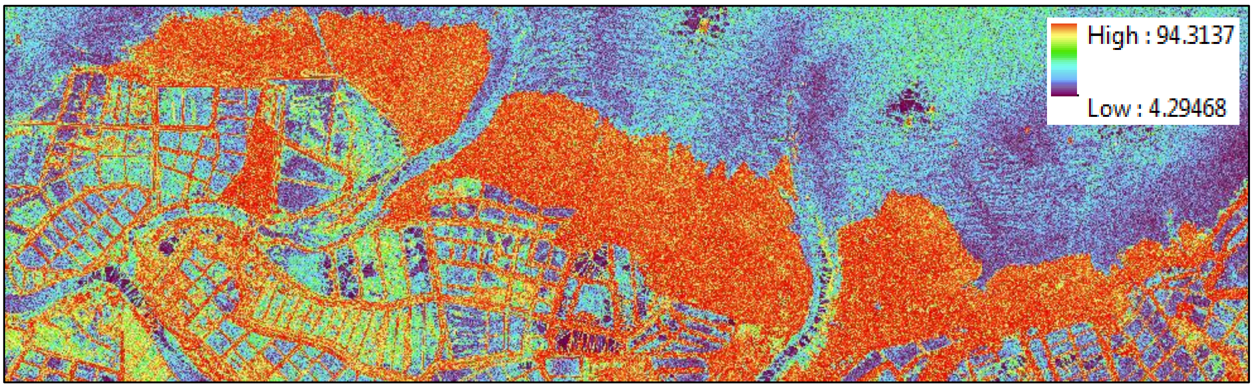

Figure 18. Principal Component Analysis (1 Band only)

2.4.5 Euclidean Distance from Mangroves: Mangroves shapefiles from Pada et al. (2016) were used for this process. The Euclidean distance layer will be used to check for the distance of the extracted fishpond shapefiles from the mangrove forest. According to ESRI (2012) The Euclidean distance function in ArcMap calculates, for each cell, the Euclidean distance to the closest source which is in our case the mangrove shapefile.

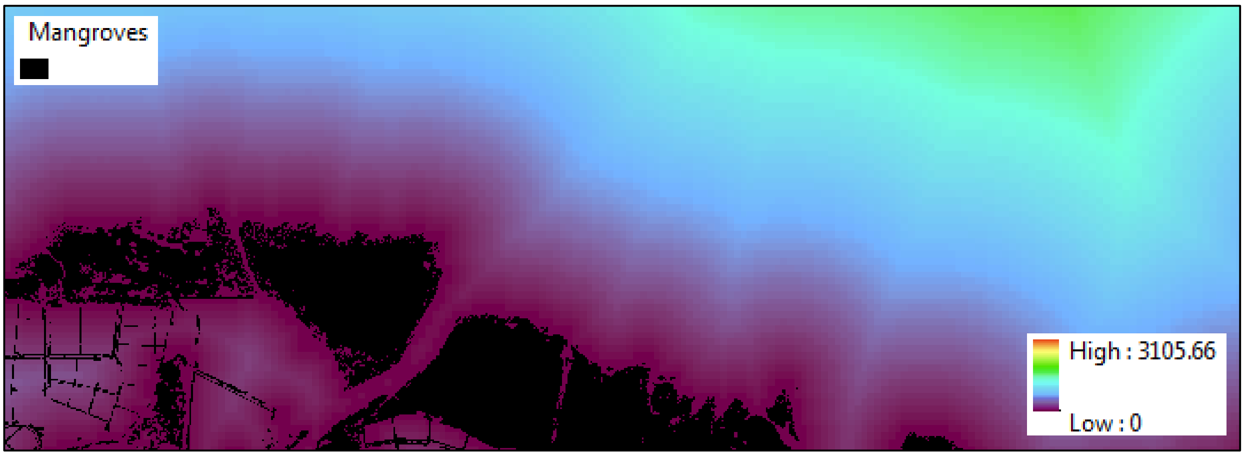

Figure 19. Euclidean Distance Raster

2.5 Fishpond Extraction

The fishponds were extracted using Object-based Image Analysis. The derivatives mentioned in Section 2.4 were used as layers for the image processing. Furthermore, shapefiles for mangroves and fishponds were also added as thematic layers.

The derivatives was first checked for regions with no LiDAR data. Using the Digital Surface Model, all pixels with values less than or equal to zero were classified as No Data. Afterwards, the portion of the image with LiDAR data was segmented. Using multi-resolution segmentation we divided the image into objects. The layer weights for the different images were as follows:

Table 1. Image Layer Weights

Layer	Weight	Layer	Weight	Layer	Weight	Layer	Weight
DSM	2	Intensity	1	PCA	1	Slope^2	5
DTM	2	NumRet	1	Slope	20	Others	0

Thematic layers for River and Mangroves were also used. A scale parameter of 75 was implemented with composition of homogeneity criterion for shape of 0.4 and compactness of 0.1.

Figure 20. Principal Component Analysis (1 Band only)

The objects were then classified to short, mid and tall. Objects with CHM values less than or equal to 0.3 was classified as short, objects values greater than 0.3 and less than or equal to 1 was classified to mid and all objects chm value greater than 1 was classified as tall. Short objects that are within the river thematic layer was then assigned as rivers.

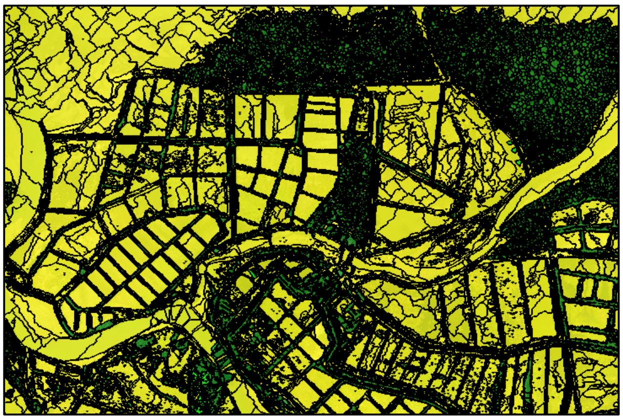

Figure 21. Short, Mid and Tall Classification

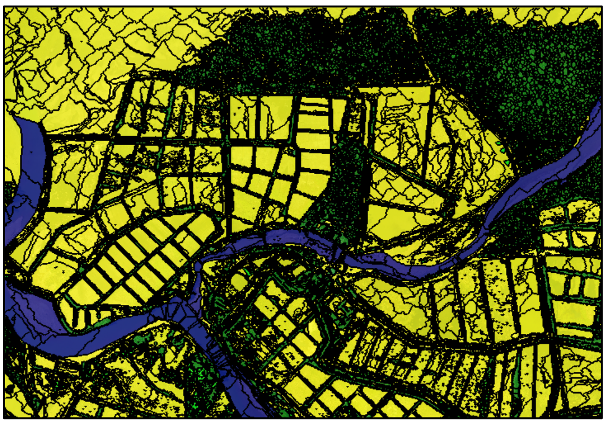

Figure 22. River Thematic Layer

Afterwards, all short objects with mean slope less than or equal to 6 were classified as water and all the water objects that has an asymmetry greater than or equal to 0.6 and mean PCA greater than 63 was assigned as dikes.

All inland water was classified as depressions or candidates for fishponds. These candidates went through a cleanup process. The cleanup methodology will depend on the area however some noticeable layers can be used such as mean DTM, mean slope of slope and area. After cleaning up, all depressions were reclassified into fishponds.

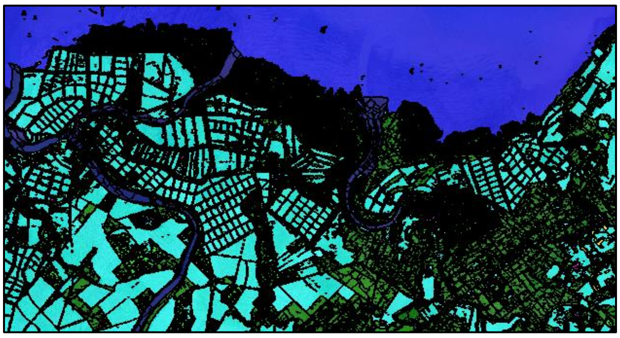

Figure 23. Image Classification before Cleanup

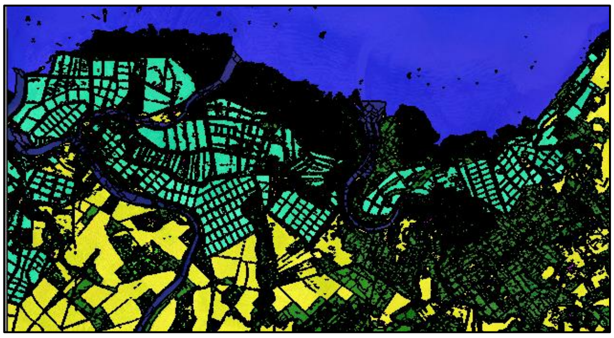

Figure 24. Image Classification after Cleanup

2.5 Abandoned Fishpond Classification

The abandoned fishpond were then classified from the extracted fishponds in Section 2.4. All fishponds with mean slope of slope greater than 40 was assigned as candidates. Since most vegetated fishponds have higher slope of slope values due to some trees and other objects inside the fishpond box.

Figure 25. Candidates with Mean Slope of Slope greater than 40

All objects with mean CHM less than 0.022 was removed from the candidates. Objects with rectangular fit less than 0.4 was also removed. Objects with length over width value greater than 6.37 was also removed. Furthermore, the final objects that were classified as abandoned were exported with their mean Euclidean distance for mangroves value.

Figure 26. Candidate Reversion Sites

3. RESULTS AND DISCUSSION

The study generated a shapefile that contains possible reversion sites for mangroves. All of the classified abandoned fishpond sites contained vegetation when checked with the existing Orthographic photograph with 0.5 m resolution.

Figure 27. Orthophotos of Candidate Reversion Sites

From the 441 extracted fishponds 57 were classified as abandoned. From the total fishponds area of 3.29 km.² it was found out that 0.45 km.² of it was already vegetated resulting into 13% of the total fishpond area to be vegetated.

Figure 28. Candidate Reversion Sites and their Distance to Mangroves

If these sites will be used for mangrove reversion efforts, the Euclidean distance of the sites from mangroves will be very helpful. The green areas in the image above are nearer to the mangroves while the red ones are farther.

4. CONCLUSIONS

The fishponds were extracted from LiDAR data using object based image analysis and was further classified as to which is abandoned by checking the vegetation through elevation models. The features that were most helpful in delineating the abandoned fishponds from the functional fishponds were mean slope of slope, mean canopy height model, rectangular fit and length/width ratio. The process resulted in successfully identifying 57 fishponds that were abandoned based on the criterions stated in the methodology of this study. Furthermore, the Euclidean distance layer is useful in identifying which features are closest to the existing mangroves. Through the workflow presented in this study, mangrove reversion sites were successfully identified by using LiDAR data.

5. FURTHER STUDIES

For further studies, the fishpond lease agreements could be used as a thematic layer so as to identify illegal fishponds and reclaiming them for mangrove reversion sites. Tidal zones shall also be considered in creating a suitability analysis. There are a lot of possible factors that shall be included in the study but due to lack of data, time and financial capability, these weren't acquired. However, initial steps for using the high resolution LiDAR data are already presented in the study thus it will be easier to replicate once more data for other factors are acquired.

6. ACKNOWLEDGEMENTS

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