MANGROVE FOREST SUITABILITY ANALYSIS IN THE CITY OF KABANKALAN, NEGROS OCCIDENTAL, PHILIPPINES

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ABSTRACT: Climate change has produced various natural anomalies in the past years, one of which was Typhoon Haiyan, recorded as the strongest typhoon to ever hit the Philippines, claiming lives and property. The national government embarked on different pursuits in reforestation, conservation and management of mangrove forests as one of the ways to address climate change especially in the past two decades. One of said projects is the National Greening Program which aims to plant 1.5 billion trees in 15,000 km² within 6 years nationwide. However, problems arose when there were no scientific basis in planting the seedlings, especially mangroves. Different mangrove species only grow in mangrove environments and not extend into other coastal ecosystems such as the beach forests, seagrass beds and beach fronts. Specific species also flourish in specific soil, pH, salinity and elevation requirements. When these are not met, said parameters become the primary reason why seedlings/ propagules planted do not have a long-term survival rate. It is therefore imperative to conduct a site suitability evaluation and analysis of the coastal areas of the Philippines to determine whether the potential areas in which to establish mangrove reforestation projects are sustainable. This study therefore aims to conduct a test suitability analysis of the mangrove forests in the City of Kabankalan, Negros Occidental, Philippines. First, extent of the natural mangrove forest and its associates were determined using Object-Based Image Analysis of LiDAR data points classified through Support Vector Machines (SVM). Map produced has an overall accuracy assessment of 98.88% (98.43% KIA). The extracted mangrove feature was then edited using manual and contextual clean-up. Next, site suitability was determined based on five geophysico-chemical parameters: Soil Type, pH (Water), Salinity, Elevation and Ecological Zonation. Representative soil samples were collected and analyzed in the laboratory to determine substrate type, water content, pH, and amount of organic matter. pH and salinity for the water column in said sites were also determined. Number of samples were determined using Stratified Random Sampling with Proportional Allocation. Elevation was based on Digital Terrain Model (DTM) while points were marked to delineate the different intertidal zones in the coastal area. Lastly, ranking of respective values for the five parameters were done and were added to obtain Sustainability values. Results show that the different mangroves species found in the site grow in 1. Soil type: loam, clay and hydrosol, 2. pH: 5.5-8.1, 3. Salinity: 0-36 ppt, 4. Elevation: 0 to $\leq$ 5 MSL and 5. Zonation: Middle to Upper Intertidal. A suitability map was generated using said five geophysico- chemical parameters delineating Most Suitable (11.05 km²), Suitable (4.32 km²), Less Suitable (2.56 km²) and Unsuitable (6.41 km²) areas for mangrove forest growth and reforestation.

1. INTRODUCTION

In November 2013, Typhoon Yolanda (international name Haiyan) caused irreparable damage to infrastructures, loss of lives and environmental degradation. In fact, it was considered as the most violent and destructive storm that ever hit the Philippines and broke world records by being the world's strongest storm recorded at landfall. It made five landfalls, affecting the islands of Leyte, Samar and Cebu.

Climate change has been pinpointed as the perpetrator of increased natural calamities, such as Typhoon Yolanda, in the past decades. Climatologists have published analyses correlating the increasing intensity of storms with the progression of climate change. Effect on the environment includes intense and more frequent storms which sometimes lead to episodic flood events, which in turn reduces water quality in coastal areas (McCulloch et al. 2003; Fabricius et al. 2005), severe heat waves or loss of arctic ice, and accelerated sea level rise (Rahmstorf 2007) among others. The combined effects of sea level rise and stronger storms have exacerbated impacts on different coastal resources across the globe (Anthony and Marshall, 2012).

One of said coastal resources are mangrove forests. Generally located in the intertidal zones of the different tropical and subtropical countries between approximately 30^0 N and 30^0 S latitude (Giri etal, 2011), they provide a number of ecological and socio-economic importance. This very productive ecosystem which is resilient to harsh environments such as a drastic change in temperature, salinity and pH serves as home to a variety of plant and animal species. To be able to adapt to its ever changing surroundings, they have developed adaptive mechanisms such as salt- excreting leaves, presence of pneumatophores (exposed roots for exchange of gases), and production of viviparous propagules (Duke, 1992).

As part of the effort to address climate change, especially increasing carbon stock sequestration and protection of its coastlines due to storm surges, the Philippines have developed numerous mangrove forest programs over the years through its Department of Environment and Natural Resources (DENR). Said programs focus mainly in the reforestation, conservation and management of mangroves especially in the past two decades. One of these is the National Greening Program or NGP. It is a nationwide rehabilitation program created in February 2011 as a means of climate change mitigation strategy and a way of reducing poverty (Herbohn et.al., 2010). Mandated through Executive Order No. 26 by then President Benigno S. Aquino III, it aims to grow 1.5 billion trees in a 15,000-km² area nationwide within a period of six years starting from 2011. 50% of the target trees are for timber production while the remaining half is intended for agroforestry.

However, as to date, there are major problems encountered in the implementation of said project. These include incorrect species selection such as *Rhizopora* sp., a default species because of its convenience, use of incorrect sites such as sandy beaches or rocky subtidal zones, reforestation over other ecosystems such as seagrass beds and dead corals, among others. This resulted to stunted growth of reforested trees and a high mortality rate. According to a study by Israel and Lintag in 2013, two years after it started that the project's performance showed that the methodology implemented by the project resulted in waste of manpower and resources. Another study by Le and colleagues in 2014 also stated that to ensure reforestation success, many technical, physical, socio-economic and institutional factors must be considered, which the project greatly lacks.

It is therefore imperative to conduct a site suitability evaluation and analysis of the coastal areas of the different municipalities and cities in the Philippines to determine whether the potential areas in which to establish mangrove reforestation projects are sustainable. This paper thus aims to develop a method using Geographic Information System (GIS) for the selection of suitable mangrove forest growth areas in Kabankalan City, the selected target test site, but only based on 5 geophysico- chemical parameters. In this way, mangroves planted will have a high chance of survival, GNP reforestation efforts will be sustainable, and trillions of pesos worth of taxpayer's money will be put to good use.

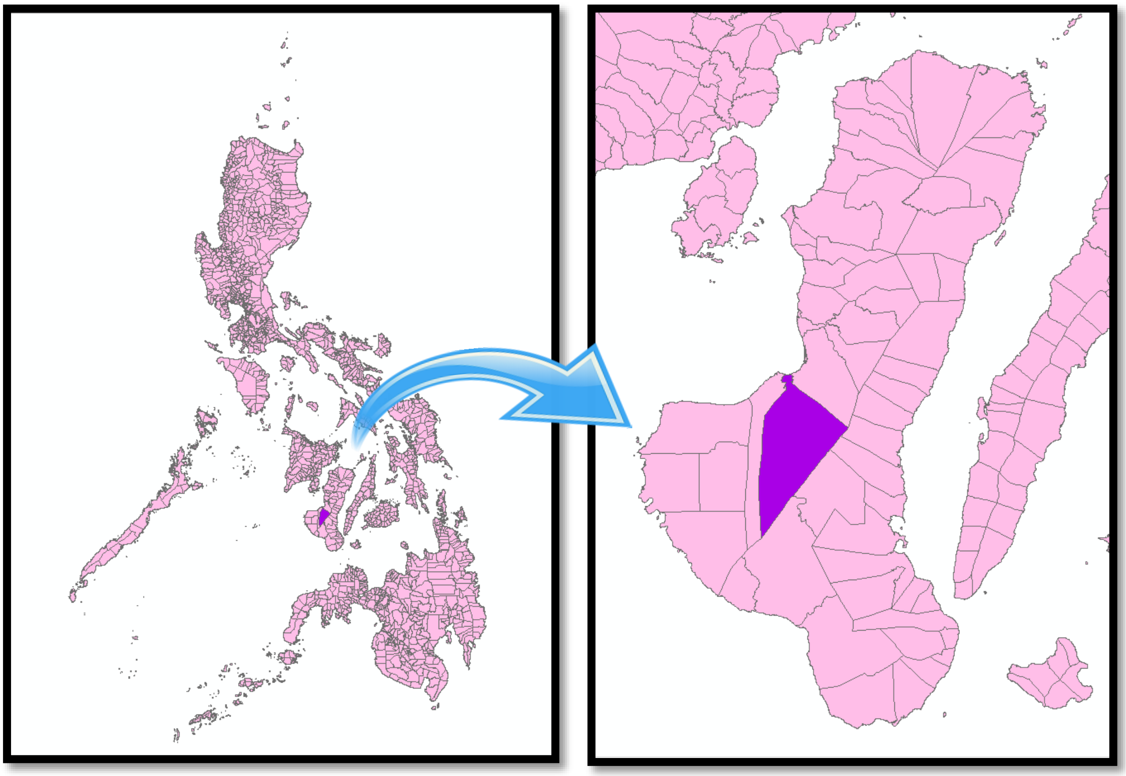

Figure 1 Location of Kabankalan City, Negros Occidental

As a brief background, Kabankalan City (seen in Figure 1), the largest city in the province of Negros Occidental and the second largest in the Negros Island Region (NIR) in the Philippines, is located 9°59' N latitude and 122°49'E longitude. This first class city is the second wealthiest city of Negros Occidental and the second largest city in Visayas in terms of land area. However, it is also the second most populous city in NIR, with a population of 181, 977 in 2015. It is bordered by the City of Himamaylan in the north, Panay Gulf in the northwest, Bayawan City of Negros Oriental in the South and the municipality of Ilog in the southwest. Originally, Kabankalan was just one of the barangays of the municipality of Ilog but was declared a town in 1903. It is 54 km long and 28 km at its widest point. Total land area is 711.35 km², with a 3.8 km shoreline of the 24.29 km² total coastal area.

Even though it only has 1 coastal barangay out of the 32 barangays of the city, its Local Government Unit (LGU) through its City Agriculturist Office (CAO) is the only one who created a Task Force Katunggan (local name for mangroves) Project, a project which employs residents, mostly fisherfolk, specifically ones living near the shore, to monitor and police human activities in the mangrove belt. Bantay Dagat (Figure 2.a-b.) (roughly translated as Ocean Guards/ Sea Patrols), in the Philippines usually is community-based and voluntary. However, through this project, they are the only paid Sea Patrols in the whole Region. Aside from patrol duty, they are also responsible for mangrove reforestation, protection and management efforts in the city's coastline.

Figure 2.a-d Shows Pictures taken during Data Collection and Field Validation in Kabankalan City. Figure 2.a Researchers at the façade of the City Hall during the Courtesy Call, 2.b. Researchers together with the Bantay- dagat while waiting for low tide, c. Frontliner propagules located inside the Mangrove Bay Watch propped with sticks to withstand wave action, 2.d. Propagules completely covered during high tide.

Established in 2008, 60 hectares (0.60 km²) was also allotted as potential mangrove forest area called Mangrove Bay Watch Reforestation Project in Sitio Bagacay, Brgy. Daan Banua as seen in Figure 2.c-d. As of today, 45 hectares (0.45 km²) has been planted with seedlings and propagules through the reforestation activities usually organized by the academe, Non- Government Agencies (NGAs), and civic club in partnership with the Katunggan Task Force. Aside from this, it has a 30 km natural mangrove belt spanning from the coastal area of two of its major rivers, the Ilog and Hilabangan Rivers.

2. MATERIALS AND METHODS

2.1 Image Analysis

The first half of the study is to determine the extent of the natural mangrove forest and its associates using Object-Based Image Analysis of LiDAR data points classified through Support Vector Machines (SVM) type of classification.

2.1.1 Pre-processing

LiDAR data used in this study has been pre-processed by the UP Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) under the Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program (UP-TCAGP, 2013).

2.1.2 Determination of Training and Validation Points (TVP)

Points were collected randomly in ArcMap using the clipped Canopy-Height Model (CHM). These points serve as the confusion points for Mangroves with other structures. They were validated in the field for their true classification. Said confusion points were then labelled with the correct class. 80% of the points per class were loaded as Training Points while 20% were loaded as Validation Points as seen in Figure 3.

2.1.3 Software Used and Layers Derived

Data processing in mangrove extraction was done using LiDAR data derivatives, namely Canopy Height Model (CHM), Digital Surface Model (DSM), Digital Terrain Model (DTM), Hillshade (HS), Intensity (Int), Number of Returns (Num Ret) and Principal Component Analysis (PCA1, PCA2, PCA3) and Slope using LASTools. The derivatives were masked with a 5 km buffer from the shore and a 500 meter buffer from the center of rivers. This composes the total study area with possible mangrove forests.

2.1.4 Decision Tree

From the LiDAR derivatives, areas with DSM values greater or equal to 0 were considered as areas with Data while areas with DSM less than 0 were considered as No Data. Areas with Data were then separated into Land and Water using DTM. DTM values which are lesser or equal to 1 were classified as water while Mean DTM values greater than 1 were classified as Land.

Remaining features for Land was then divided into tall and short structures using values for Mean CHM. Land features with a Mean CHM which is greater than 1 are further classified as Nonground while land features with a Mean CHM of less than or equal to 1 are classified into Ground. Aquaculture and River shapefiles were loaded as Thematic Layers. Only the Nonground class is used during SVM type of classification in the eCognition software. Ground features were further classified to Fallow and Short Vegetation for visual purposes only.

2.1.5 Ruleset followed to produce Final Classes

Ruleset used is divided into 4 major levels such that changes in the next level can be implemented without deleting the whole level. Level 1 is composed of Multi-threshold and Multi-resolution segmentation. Other layers are also derived in this level such as Normalized Digital Surface Model (nDSM). Level 2 is application of River and Aquaculture shapefiles as Thematic Layers. And assignment of ground features as fallow and short vegetation. These classes are just used for visual inspection. Level 3 is where the SVM is applied using the Nonground class based on four classes, namely, Buildings, Mangroves, Other Trees and Sugarcane from the TVP collected. Level 4 is more on contextual editing and clean-up. It utilizes editing using the Assign Class using Mean values, Distance to and Relative Border to features.

2.1.6 Post-data Processing

Accuracy Assessment (AA) was done using the Accuracy Assessment Tool in eCognition. Only final classifications with a 90-100% AA and a kappa coefficient of .9 to 1 are accepted. Training and validation points were added if the AA does not fall on this range.

Finally, only the mangrove shapefile is exported to be used for the second part of the study.

2.2 Determination of Physico- chemical characteristics

The second half of the study is site suitability determination based on five geophysico- chemical characteristics namely, soil type, salinity, elevation, ecological zonation and water pH.

2.2.1 Sampling

Representative soil samples should be collected and analyzed in the laboratory to determine substrate type, water content, pH, and amount of organic matter. In order to do this, first, the number of samples to be collected were determined using Stratified Random Sampling with Proportional Allocation using soil shapefiles from the provincial LGU as preliminary raw data. It uses the following formula thus:

$$n = \frac{Z_{\alpha}^{2}(p)(q)}{d^{2}} \quad (1)$$

Where:
Z_{α} is the standard normal deviate coefficient for a given level of confidence (α) (*Please see table* 1)
p is the approximate mean proportion; $q = 1 - p$
d is the desired level of precision as a decimal percentage, use a value of 0.05 for d
(Ellingham et al., 1998)

Table 1: Standard Normal Deviate Coefficients (Z_{α}) for Common Levels of Confidence

Confidence Level	Alpha (α)	Z_{α}
80%	0.20	1.28
90%	0.10	1.64
95%	0.05	1.96
99%	0.01	2.58

Where:
p = Proportion of Coastal Area to the Total Area of Kabankalan City
q = 1 – p Proportion of Non-coastal Area to the Total Area
d = Desired Precision is 95% which means allowable error is 5% = 0.05

Consequently, the following formula was used in determining the number of sample points in the collection of physico-chemical data:

$$nh = \left(\frac{Nh}{N}\right)(n) \quad (2)$$

Where:
nh is the number of samples in soil type h
Nh is the area of soil type h
N is the total coastal area
n is the number of samples

2.2.2 Physico-chemical data collection

Each point was navigated using GPS (3m accuracy). At each point, pH and salinity of water (either from river or the ocean if present) were measured through Grab Sampling. This was done by immersing a 500 mL beaker in the water and collecting samples at mid-depth to the surface. Then, the pH meter's probe was cleansed with distilled water, immersed in the beaker containing the water sample and was taken out after 2 minutes (or once digital display stabilizes). The same procedure was done using a refractometer. pH and salinity values were then recorded in a data sheet with container labels, sample source, time and date of collection and environmental conditions.

A 1 kg soil sample was also collected using a trowel and put in individual plastic bags. Said samples were tested in the laboratory for pH, amount of organic matter and mechanical type (final soil class). If point is near the ocean, the Highest High Tide (HHT) and the Lowest Low Tide (LLT) were noted as to determine the different intertidal zonations in the shore and were marked using GPS. pH and salinity sampling were done before soil collection as to avoid contamination.

2.2.3 Shapefile Preparation and Ranking

pH, salinity, soil type and ecological zonation points were converted to polygon shapefiles. The extent used in the first part was used for the clipping of the DTM to be used as basis for elevation, as well as the shapefiles of the remaining parameters.

Ranks were assigned to values for slope, pH (water), salinity, ecological zonation and soil class. Suitable values are assigned as 5 and not suitable values are assigned as 1. Final suitability was determined by adding the rank for the five parameters. Values ranging from 0-11 were considered as Unsuitable, 12-15 as Less Suitable, 16-19 as Suitable and 20-25 as Most Suitable.

3. RESULTS AND DISCUSSION

3.1 Image Analysis

All available LiDAR data for the coastal area of Kabankalan City was processed for this study. Manual classification was done in the vertical data shift near the edge because water was classified as tall objects. Also, the mangrove features in the map may seem to have been abruptly cut but this is just based on the available LiDAR derivatives. Holes are present in the map because these have no LiDAR data coverage anymore. Final classes that were produced were visually inspected for misclassifications. Manual editing and contextual clean-up is generally used especially if misclassification is based on data limitations.

No manual editing was done in eCognition for Sugarcane, Other Trees, Built-up and Mangroves since they already produce acceptable user, producer and overall accuracy assessments after Level 4. Misclassified objects are further refined using ArcMap.

Final Map is seen in Figure 4. Classes in the map include Buildings, Fallow or Bareland, Fishponds, Mangroves, Other Trees, Short Vegetation, Sugarcane and Water. Generated map has an overall accuracy of 98.88% with a KIA of 98.43% as in Figure 5.

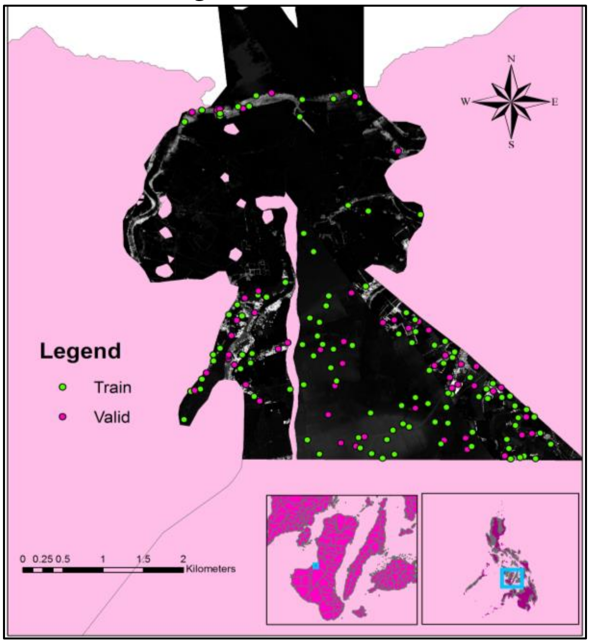

Figure 3 Shows Training and Validation Points

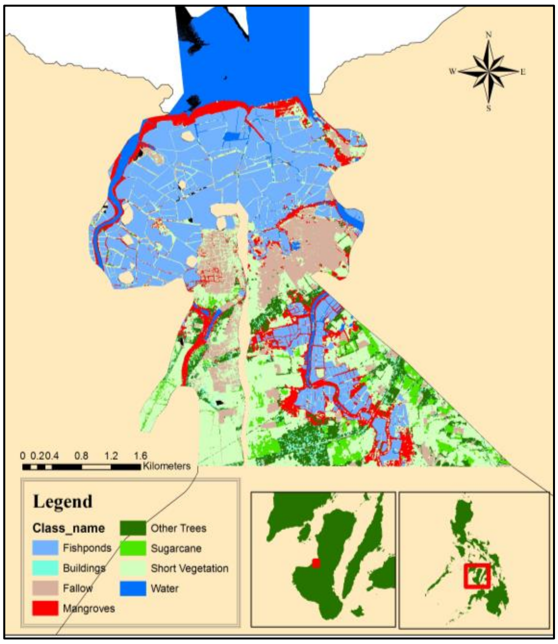

Figure 4 Shows the Final land Cover Map of Kabankalan City

User \ Referenc...	Bu	SC3	Mgr	OTr	Sum
Confusion Matrix					
Bu	858	0	0	0	858
SC3	0	2855	0	0	2855
Mgr	0	0	1495	85	1580
OTr	0	0	0	2331	2331
unclassified	0	0	0	0	0
Sum	858	2855	1495	2416	
Accuracy					
Producer	1	1	1	0.9648179	
User	1	1	0.9462025	1	
Hellden	1	1	0.9723577	0.982	
Short	1	1	0.9462025	0.9648179	
KIA Per Class	1	1	1	0.9493239	
Totals					
Overall Accuracy	0.9888510				
KIA	0.9842878				

Figure 5 Shows Accuracy Assessment with its corresponding kappa coefficients

3.2 Physico-chemical Characteristics

There are 3 types of soil in Kabankalan City- clay, hydrosol and loam. Based on the formula in the sampling design, the number of samples are 2, 19 and 25 for loam, clay and hydrosol, respectively at 95% confidence level. Although mangroves flourish in a variety of soil types, they mostly occur in soil with clayey properties in their natural conditions but can include loam, sandy loam, clay, hydrosol and sometimes sand (Adam, 1990). However, only clay and hydrosol have existing mangrove forests in the said city.

According to Soto and Jimenez in 1982, mangroves flourish in waters with a salinity of 25-55 psu (≈25-55 ppt). Values obtained from the field ranged from 1-36 ppt. This may be due largely because at the time of sampling, it is already the rainy season. Also, freshwater input from the two major rivers play important roles in changing values for salinity. Based on results, salinity values acquired ate still within the acceptable values.

Elevation values were based on DTM. According to a study by Clarke and Hannon in 1969, mangroves can be found from 0.05-5 meters above MSL. Using this data, raster values from DTM was converted to polygon to delineate high ground in which mangroves do not grow anymore.

Different mangrove species only grow in mangrove environments and not extend into other coastal ecosystems such as the beach forests, seagrass beds and beach fronts. They grow best below the Highest High Tide Water Mark (Upper Intertidal) and just before the Lowest Low Tide (Middle Intertidal). Beyond the HHTW is the Supratidal Zone wherein Beach Forests are found while beyond the LLTM is the Lower and Subtidal Zones wherein Seagrass Beds and Corals are already found (Primavera etal., 2012). Survival rate is low in the intertidal extremes since the Supratidal Zone is already dry land and not fed by rivers or the ocean while the Lower and Subtidal Zones are already completely submerged in water, one constraint that limits the exposure of the mangrove leaves and stems for photosynthesis inhibiting growth and survival.

pH values for ambient water in mangrove forests ranged from 5.5-8.1. Results show that the pH in the coastal and riverine waters of Kabankalan City range from slightly acidic to mildly basic. Results of the water pH sampling in the rivers and oceans of Kabankalan City is within the permissible limits (Behera etal., 2014). However, it was worth to note that the acidic pH values were more concentrated near aquaculture ponds and water directly beneath the mangrove trees. This may be because of fish meal and leaf litter degradation making the water near these areas acidic.

Table 2 below shows the different values and classification results and their assigned Ranks. Ranking is from 1-5, with 5 as the most suitable and 1 as the least suitable. Corresponding variations to the ranks assigned was based on outlier values wherein mangroves can still grow but follows a restricted/ inhibited growth.

Table 2 Shows the Ranking of the Parameters based on unique parameter classes

#	GEOPHYSICO- CHEMICAL PARAMETER	VALUE/ CLASSIFICATION	RANK	REFERENCES
1	Soil Type	Loam	5	Almulla, 2013
		Clay	5	
		Hydrosol	5	
		Sand	1	
2	Salinity	30 ≥ ppt ≥ 8	5	Duke 1993
		31 < ppt < 9 (outliers)	3	
		No Seawater	1	
3	Elevation	Less than or equal to 5 m from MSL	5	Clarke 1969
		More than 5 m from MSL	1	
4	Ecological Zonation	Upper Intertidal	5	Pimavera 2012
		Middle Intertidal	3	
		Supra Intertidal	1	
		Lower Intertidal to Subtidal	1	
5	Water pH	6 ≤ pH ≤ 7.5	5	Joshi 2003
		5.99 > pH > 7.56 (outliers)	3	
		5.5 > pH > 8.1	1	

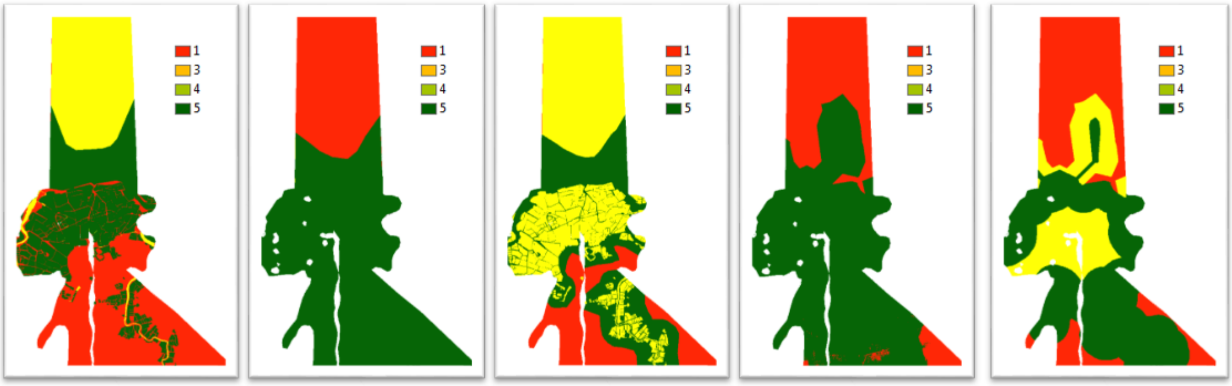

Figure 6 a-e Mangrove Suitability Analysis Factors tested in this study: 6.a Salinity, 6.b Soil, 6.c Water pH, 6.d Elevation and 6.e Ecological Zonation.

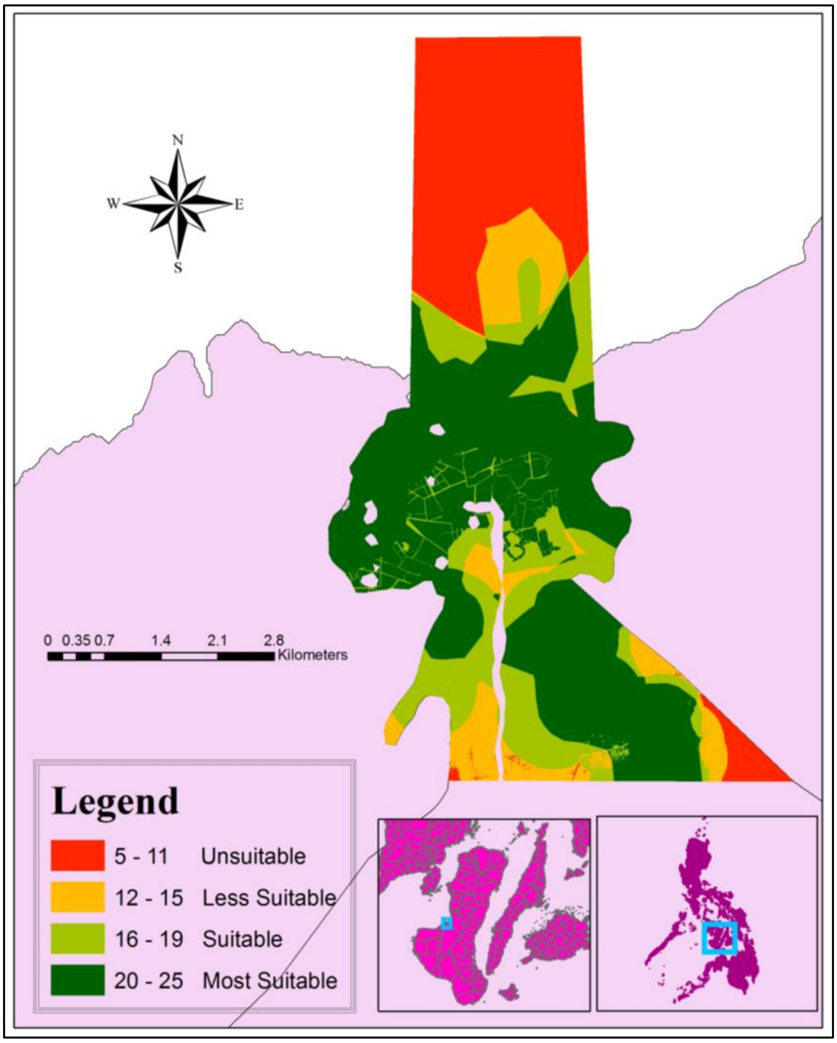

Figure 7 Mangrove Suitability Map in Kabankalan City, Negros Occidental

Figure 7 is the Suitability Map of Kabankalan City, Negros Occidental. The areas most suitable for mangrove growth is shown in dark green, followed by light green (suitable) areas then by yellow (least suitable). Red areas are restricted for planting since these areas are already deemed as unsuitable for mangrove growth. Mangroves planted in the Most Suitable and Suitable areas will have an optimized growth while mangroves planted in the Unsuitable areas will have 100% mortality. Mangroves planted in Less Suitable areas will have stunted growth.

Areas calculated are 11.05 km² for Most Suitable, 4.32 km² for Suitable, 2.56 km² for Less Suitable, and 6.41 km² for Unsuitable areas respectively. Presently, only 0.90 km² are covered with mangroves, with objects within the most suitable area. There are no mangroves planted in the Unsuitable sites. However, to maximize the full potential of the coastal area of Kabankalan City, it is advised to use at least the Suitable and Most Suitable areas.

4. CONCLUSION

Mangroves were extracted in Kabankalan City, Negros Occidental using OBIA through SVM classification with an overall accuracy assessment of 98.88% (98.43% KIA). Total area is 0.90 km².

Mangrove trees flourish in specific soil, pH, salinity, ecological zonation and elevation requirements. When these are not met, said parameters become the primary reason why seedlings/ propagules planted do not have a long-term survival rate. A suitability map was generated using said five geophysico- chemical parameters delineating Most Suitable, 4.32 km² for Suitable, 2.56 km² for Less Suitable, and 6.41 km² for Unsuitable areas for mangrove forest growth and reforestation.

5. RECOMMENDATION

Since this study only uses 5 parameters, it is advised to test other parameters such as hydrology (ocean current, fresh water supply, amount of pollution, etc), amount of organic matter, sediment particle size/ substrate and amount of rainfall/ weather patterns/ climate, among others as to have a more holistic approach in the suitability analysis of mangroves. Modifying the values for these said parameters based on your region will produce different results. It is also recommended to test different effects of different parameters to specific species.

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