INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 11, No. 4, p. 74-88, 2017
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Seagrass mapping and assessment using remote sensing in the Municipality of Kauswagan, Lanao del Norte, Philippine

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Article published on October 15, 2017

Key words: Conservation, Coastal resources, Remote sensing.

Abstract

Field base *in situ* sampling is the traditional way to assess sea grass meadows, but it is time consuming and expensive. At present alternative methods for assessing sea grass is through airborne or satellite based sensors. Softwares such as Arcmap and ENVI were used to further enhance the quality of the distribution of resources. These alternative methods produce cost effective and repetitive sources on seagrass distribution over wide areas in a shorter time. This paper conducted a research study on seagrass mapping and assessment in Kauswagan Lanao del Norte. Based from the map the municipality had wide seagrass meadows and wide intertidal area. The total area of resources mapped for Kauswagan is 199 hectares with seagrass area of 183 hectares. The accuracy of the map was 90%. The accuracy is enough to justify the distribution of the resources mapped. A total of six (6) species of sea grass were identified in Brangay Tacub, Kauswagan, Lanao del Norte. The most abundant seagrass in terms of cover and density is the species *Thallasia hemprichii* with a percent cover 79% and shoot density of 1021 shoots/m^2 . Seagrass condition was based on Fortes' criteria; seagrass in barangay Tacub was considered good despite the anthropogenic pressures present in the areas such as pollution, the effects of gleaning and the presence of a coal powered plant. All values for diversity show moderate diversity (H'=1.33-1.54), high eveness (E= 0.70) and low dominance values (D= 0.30) indicating well-distributed species and no dominant species.

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Introduction

Major marine ecosystems composed of coral reefs, mangrove forests and sea grass meadows provide food and shelter especially for fishes and other marine organisms (Honda *et al*., 2013). The coastal ecosystem of the Philippines are some of the most productive and biologically diverse in the world. It comes next to Australia in terms of sea grass diversity in the world with 16 species (Fortes, 1989).

Sea grasses, flowering plants that survive in saline water levels inhabit shallow coastal areas (Short *et al*., 2007; Yaakub *et al*., 2013). They possess leafy shoots and creeping rhizomes that can attach to all types of substrates thus forming sea grass meadows (Fortes, 2008) ; enhancing biodiversity and habitat diversity of coastal waters by supporting the production of marine organisms especially economically important fishes, shellfishes and crustaceans (Choo, 2008; Fortes, 2012; Honda *et al*., 2013). Also they stabilize and reduce sediment loads in the water thus playing an important role in the global carbon cycle and nutrient cycles thus improving water quality (Beach & Moore, 2004; Waycott *et. al*., 2009).

The traditional way to assess seagrass meadows in terms of diversity and distribution is through field based in situ samplings (Fortes *et. al*., 2008) but at present an alternative method for assessing sea grass composition for conservation and management is through the use of airborne or satellite based sensors such as Landsat TM, LiDAR, MODIS and World View (Hossain *et. al,* 2014). These alternative methods produce cost effective and repetitive sources on the information of sea grass distribution over wide areas in a shorter time than doing field surveys. In conjunction with field survey monitoring, remote sensing maps provide a better understanding of the extent of spatial and temporal trends in the seagrass resource (Meyer and Pu, 2012).

Satellite remote sensing imagery through Landsat 7 is used in this study, it is a newer multispectral satellite developed by the United States Geological Survey (USGS) that aims to provide scientists and engineers data to monitor and manage earth's resources.

With the increase of the country's population, human impacts through anthropogenic activities on the sea grass habitats had been a major concern (Meyer and Pu, 2012). Sea grass beds are in decline (Cardoso *et al*., 2004; Waycott *et al*., 2009).Fortes' (2008) study on sea grass areas showed that 30 – 40% of sea grass areas in the country have been lost in the last 50 years and now are distributed over about 27,282 sq.km. The decline of sea grass meadows is alarming and its effect had been affecting the marine ecosystem because without sea grass beds; mangroves and coral reefs cannot sustain the demands of the aquatic environment. Conservation of this important habitat is lagged behind the other coastal ecosystems for its value is not so much on its direct use but on the services it provides to the overall functioning of the marine ecosystem (Al-Wedaei *et al*., 2011, Fortes, 2012).

In the Philippines efforts on conserving this ecosystem is present; a sea grass demonstration site was established in Bolinao, Pangasinan and a sea grass sanctuary in Narra, Palawan. In the 4th Philippine national report on the convention on biological diversity, the Philippine National Sea grass Committee published the Philippine National Sea grass Conservation Strategy and Action Plan, an integrated approach to address sea grass-related issues and concerns but these programs are not followed locally especially on the provincial scale where its conservation is usually under mangrove and coral conservations in marine protected areas.

The presence of a 552 MW coal powered plant that is ongoing construction phase had altered the coastal environment in one of this paper's study areas thus this paper provides remotely sensed baseline map of sea grass meadows as well as other coastal resources and additional data on the sea grass biodiversity. The key to have a sustainable coastal management is a reliable data set.

Materials and methods

Study area

The Municipality of Kauswagan is the second coastal municipality of the Province of Lanao del Norte, it lies on the mid-central portion of the Northwestern Mindanao coastline (8° 9' 35'' N, 124° 5' 51'' E) and is located along the coast of Iligan Bay (Fig.1) thus the coastal areas of the municipality is rich in sea grass cover thus fishing, shellfish and echinoderm gleaning are present and are sources of livelihood.

Fig. 1. Map of Iligan bay where the municipalities of Bacolod and Kauswagan are located.

Portions of the coastal area of barangay Tacub (Fig. 2) are identified as Marine Protected Areas by the Department of Environment and Natural Resources (DENR-10).

Seagrass mapping

Sea grass in the following sites were extracted from high resolution multispectral imagery. Publicly available Global Land Survey (GLS) 2000 Landsat 30-m resolution data were used to map the extent and spatial distribution of the sea grass meadows for the year circa 2016. Data was acquired from the U.S. Geological Survey (USGS) Earth Resources Observation and Science Center. Considered in the download of the images are the absence of clouds. Data processing will be through existing Geo Cover and Landsat archive to produce near-global, cloud-free mosaic. (Long and Giri, 2011).

To correct the radiometric and atmospheric errors from the acquisition and recording of data from the instrument used by Landsat and also because of the effects of wavelength dependence of solar radiation; Image preprocessing is done (Fig. 3). Then the image undergoes resizing and masking to subset the calibrated and corrected image using ROI and mask the non-water regions of the map such as land cover and clouds for easy classification of the benthic sources (Japitana and Bermoy, 2004). Validation and Training points collected in the field mapping are processed into shapefiles and are used in the supervised classification of the image. The entire image pre-processing, classification and accuracy assessment is completed using the tools in Arc Map 10.1 and Exelis Visual Information Solutions ENVI 5.1 software.

The Spectral Radiance (Lλ) for Landsat images was given by (https://landsat.usgs.gov/Landsat8_Using_Product.php) as mentioned by Japitana and Bermoy (2016):

Lλ= MLQ cal + AL (1)

Where:
ML = Band-specific multiplicative rescaling factor from Lands at metadata
(RADIANCE_MULT_BAND_x, where x is the band number)
AL = Band-specific additive rescaling factor from Landsat metadata
(RADIANCE_ADD_BAND_x, where x is the band number)
Qcal = Quantized and calibrated standard product pixel values (DN)

FLAASH algorithm used is as follows:
Lo (λ) =Lsun (λ) T (λ) R (λ) cos (θ) + Lpath (λ)
where: λ= the wavelength Lo(λ) = radiance received by the sensor
Lsun (λ) = the atmospheric layer above the sun radiance
T (λ)= the total transmission of the atmosphere
R (λ)= the reflectance of the surface Resizing and masking
Θ = the angle of observation
Lpath (λ) is the scattering radiance lane

Seagrass composition and diversity

Establishment of sampling stations

The transect-quadrat method was used in this study. The barangay has 3 stations and in every station 3 transect lines were established (Fig. 4). Transect lines (200m) are placed perpendicular to the shoreline where the habitat starts. Transect lines are 100 m – 150m apart from each other (English *et. al.,* 1997). Quadrats (0.5m x 0.5m) that are divided further into 25 smaller squares (0.1m x 0.1 m) were placed at both left- right sides along each transect line at 20m intervals.

Seagrass composition, percent cover, shoot density and condition

Seagrass species present in the quadrat were identified, percent cover were estimated and recorded using the SeagrassNet percentage cover photo guide (appendix) which is based on the methods of Short et.al (2006). Species identification and classification were based on pictures and descriptions on references from Philipps and Menez (1988) and Calumpong and Menez (1997). A 0.5m x 0.5 m quadrat was used to estimate the percent cover for all species of seagrass. Density of each species of seagrass will be determined using a non-destructive technique by counting each seagrass shoot within each quadrat. For Enhalus acoroides species, density will be directly counted within the 0.5 x 0.5 m quadrat. Sub-sampling for density using one 0.25 x 0.25 m quadrat will be used to quantify density of the smaller seagrass species such as Thalassia sp., *Cymodocea sp., Haladule sp. And Halophila sp.* which will be found in numbers within a 0.5 x 0.5 m quadrat.

Condition of Seagrass (Table 1) was determined using the criteria set by Fortes (1989).

The data was analyzed by computing the average percentage cover of each transect; dividing the total per transect by the number of quadrats. The average in each transect were then added and divided by the number of transects in the survey to compute for the percentage cover for the whole site (Ame & Ayson, 2009).

$$\text{Seagrass shoot density (D)/quadrat} = \frac{\textit{Number of shoots (N)}}{\textit{Specific area of quadrat } (m^2)}$$

Statistical analysis

Ecological indices such as Shannon-Weiner, Margalef's index of richness and Pielou's index of evenness were calculated. Paleontological Statistics Software (PAST version 3) was used to analyze occurrence and dominance of sea grass species.

Results and discussion

Seagrass mapping

In order to effectively manage the sea grass meadows in barangay Tacub Lanao del Norte, the seagrass meadows were mapped. The map produced is a baseline sea grass map that can be used by the local government and stakeholders on the distribution of seagrass in the municipality.

Table 1. Criteria on seagrass condition for habitat assessment.

Excellent	76-100 %
Good	51-75 %
Fair	26-50 %
Poor	0-15%

Source: PCRA Manual.

Table 2. Total Area of coastal resources found in Kauswagan and Bacolod, Lanao del Norte.

Coastal Resources	Kauswagan (hectares)
Algae	1
Corals	7
Sand	8
Seagrass	183
Total	199

Compared to the traditional coastal mapping of seagrass through manta tow and field surveys which consumes a lot of time and manpower, (Lennon, 1989) Mapping using satellite remote sensing such as Landsat is an effective way because the data can be downloaded free; assessing the sea grass area can be done easily and because of its availability it can be used for monitoring yearly changes. The map acquired in this study distinguished the different coastal resources. Based from the map the municipality had wide sea grass meadows as well as a wide intertidal area.

Table 3. Seagrass species found in the study area: Brgy Tacub, Kauswagan Lanao del Norte. Legend: S1- Station 1, S2- Station 2 and S3- Station 3.

		Kauswagan		
Seagrass species	Common name	S1	S2	S3
Thalassia hemprichii	Dugong grass	✓	✓	✓
Enhalus aceroides	Tropical eel seagrass	✓	✓	✓
Halophila ovalis	Spoon grass	✓	✓	✓
Haladule pinifolia	Fiber- strand seagrass	✓	✓	✓
Haladule uninervis	Fiber- strand seagrass	✓	✓	✓
Syringodium isoetifolium	Syringe grass	-	-	-
Cymodocea rotundata	Round-tipped grass	✓	✓	✓
Total number of species		6	6	6

The Coastal area of Kauswagan was mapped based on four classes of resources found in the area (Fig. 9). The total area of coastal resources mapped in Kauswagan was 199 hectares (Table 2). Sea grass dominated the area with 183 hectares represented by the green color (Fig.9), expanding from the beach area until the intertidal edge.

The next abundant resource is sand with 8 hectares mostly found in between barangay Tacub and Bagumbayan where the construction of the power plant was located; during the coastal mapping in the field not all portions of the coastal area of Tacub was sampled because the area where the power plant was, cannot be accessed due to security reasons.

Table 5. Seagrass cover and condition per station for Bacolod and Kauswagan,Lanao del Norte.

	Cover (%)	Condition (Fortes)
KS1	77	Excellent
KS2	75	Excellent
KS3	51	Good
Average Kauswagan	68	Good

Table 5. Diversity indexes in each stations in Kauswagan.

	Ecology Index			∑ Species	∑ Shoot
Station	H'	E	C		
K1	1.54	0.78	0.2644	6	2039
K2	1.33	0.63	0.3422	6	2600
K3	1.35	0.64	0.3452	6	1572
Average	1.43	0.7	0.3106	6	2070

The coral reef with an area of 7 hectares was only present in the intertidal edge since the coastal topography of Kauswagan is a sloping reef. Last resource mapped was the presence of algae represented by algae beds and *Sargassum* sp. With 1 hectare. Sea grass was found throughout the intertidal area of the municipality.

Fig. 2. Seagrass meadow in Barangay Tacub, Kauswagan Lanao del Norte.

The sea grass area in Kauswagan had a total area of 183 hectares (Fig.9).

Seagrass composition

Barangay Tacub was assessed for sea grass biodiversity that exhibited extensive mixed sea grass meadows composed of 6 species from 2 Families Potamogetonaceae and Hydrocharitaceae (Fig. 10 & 11) that occupy most of the intertidal flat.

The species (Table 3) belonging to family Potamogetonaceae under the sub family

Cymodoceaeceae are *Cymodocea rotundata, Haladule uninervis* and *Haladule pinifolia* (Fig.10) while the species *Enhalus acoroides*, *Halophila ovalis* and *Thalassia hemprichii* belong to family Hydrocharitaceae (Fig.11).

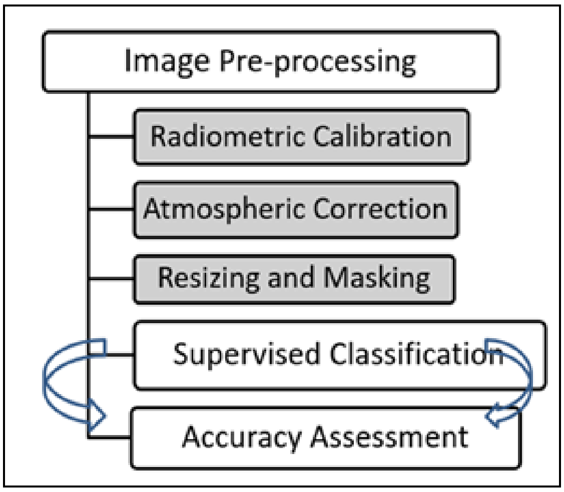

Fig. 3. Flow chart of Seagrass Mapping.

Species under family Potamogetonaceae , sub family Cymodoceaeceae can be distinguished based on the leaves differentiated into a sheath and blade with the presence of a ligule; which is a membranous projection at the junction between the sheath and the leaf blade (Calumpong and Menez, 1997).Since each barangay is a mixed seagrass meadow, the species found have a distinct size range; from the smallest *Halophil*a species to the larger *Enhalus* species (Vernaat *et al*., 1995).

Compared to the 16 species that is present in the Philippines (Fortes, 1989;; Menez *et. al,* 1983; Calumpong and Menez, 1997) the seagrass in both municipalities each have 6 species, about 33% of the total seagrass found in the country. With regards to the recent published studies around Lanao del Norte both study areas have more seagrass identified than the 5 species found along the coastal areas of IliganCity (Orbita and Gumban, 2014) and Linamon, Landao del Norte(Malugao and Orbita, 2010). Both study areas though were a species short from the 7 species Estanol *et. al* (2015) observed in his study on *Thalassia hemprichii* abundance and biomass for the whole coastal area of Kauswagan, Lanao del Norte. All the 6 species found in this study were also present in the study of Uy *et al.* (2006) in his assessment of Seagrass Meadows in the Costal Barangays of Northeastern Mt. Malindang that observed 11 species.

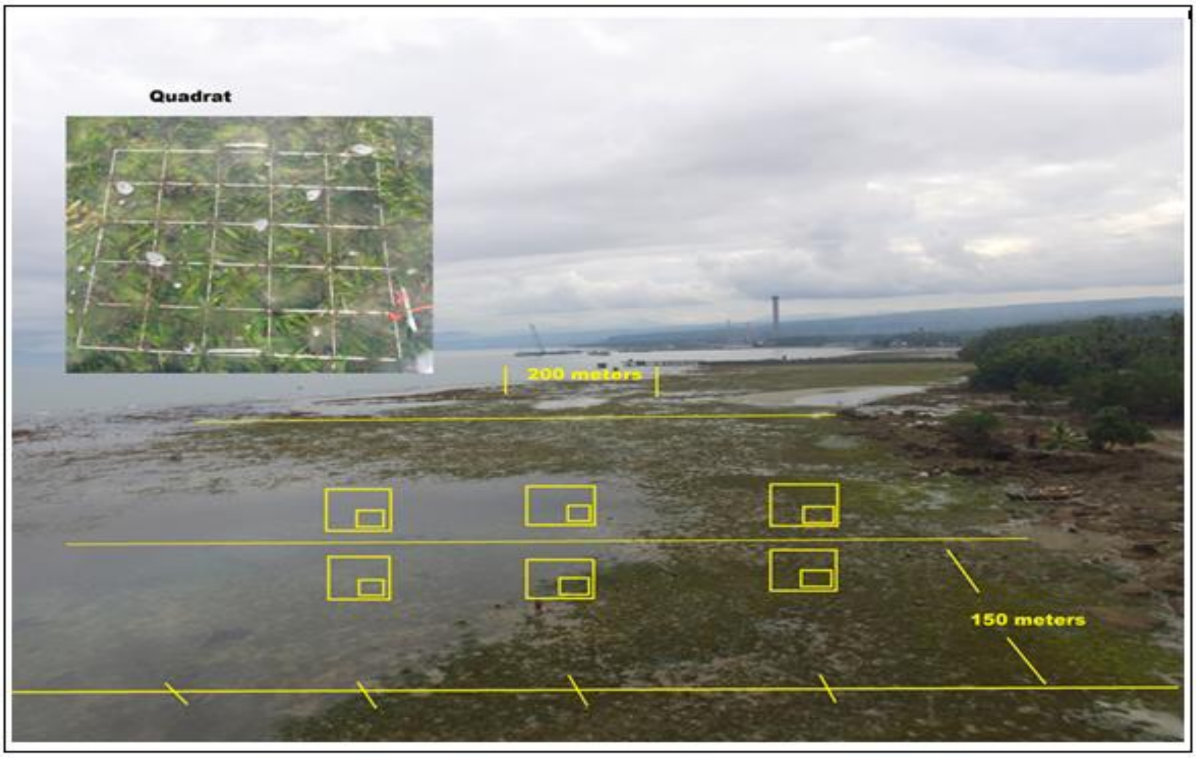

Fig. 4. Establishment of transects along the coastal area of Brgy. Tacub, Kauswagan Lanao del Norte.

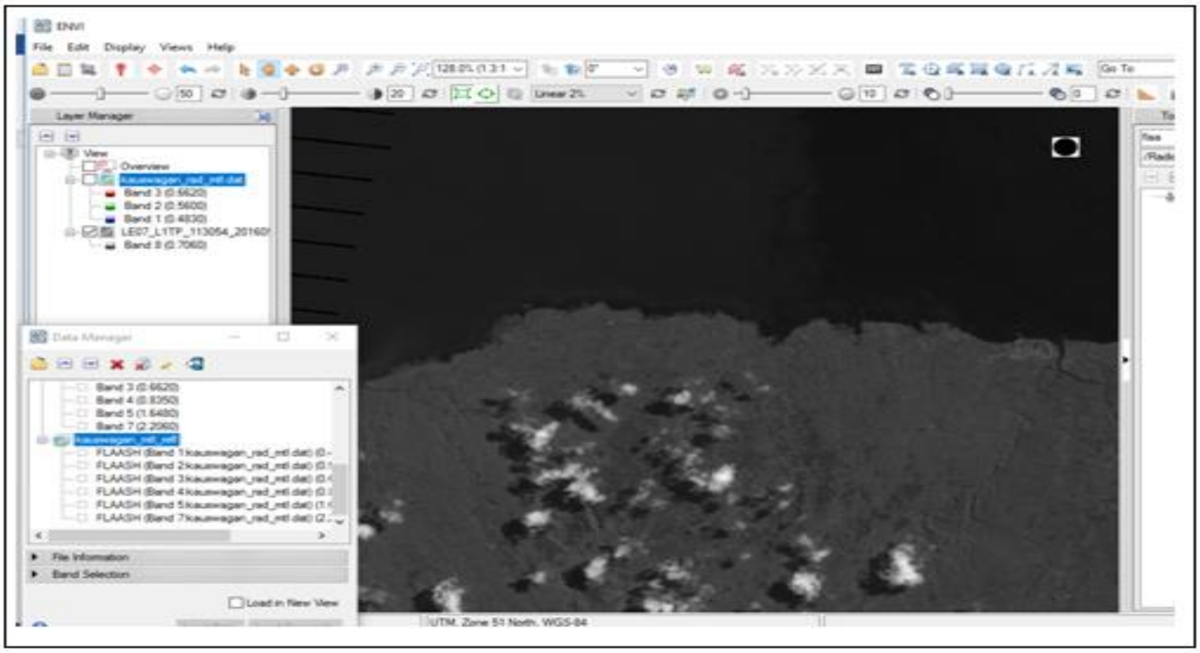

Fig. 5. Baseline map of Tacub Lanao del Norte from Landsat 7.

Fig. 6. Map showing the masked potion of Kauswagan, Lanao del Norte.

Seagrass Cover, Shoot Density, Abundance and Sea grass Condition

Percent cover and shoot density are widely used parameters for assessing and monitoring changes in seagrass meadows. Tacub had a total average percent cover of 151 and total shoot density of 2042 shoots/m^2. Total shoot density per species ranges from 72 m^2 – 1021 m^2.In terms of the relative cover and shoot density for each species, *Thalassia hemprichii* had the highest relative cover of 52% with a shoot density of 1021shoots/m^2; followed by Enhalus *aceroides* with *18%, Cymodocea rotundata 16%* , Haladule *pinifolia* with6%; while the lowest relative cover and shoot density of 4% ,115shoots/m^2 belongs to *Haladule uninervis* (Table 4).

The percent cover for *Thalassia hemprichii* is highest in Station 2 with 92 % and lowest in Stations 3, 67%, this is probably caused by the short intertidal flat found in Station 3 that ranged from 40 – 200 meters per transect and also cover was less for all species because it is near the community, the construction of the power plant and the sediment observed was composed mainly of sand. *Enhalus aceroides* that is next to *Thalassia hemprichii* had the highest cover 44% in station 1 which is the station beside a river; cover is high due to the effect of the muddy-sandy substrate which is favorable to *Enhalus aceroides* (Calumpong and Menez, 1997; Fortes, 2013). *Cymodocea rotun*data had the highest cover of 38% in Stations 2 while lowest in Station 3 with 16 %. *Haladule uninervis, Haladule pinifolia, Halophila ovalis* the smaller species of seagrasses found in Tacub all have close percentage cover between 6 %-9% in all stations.

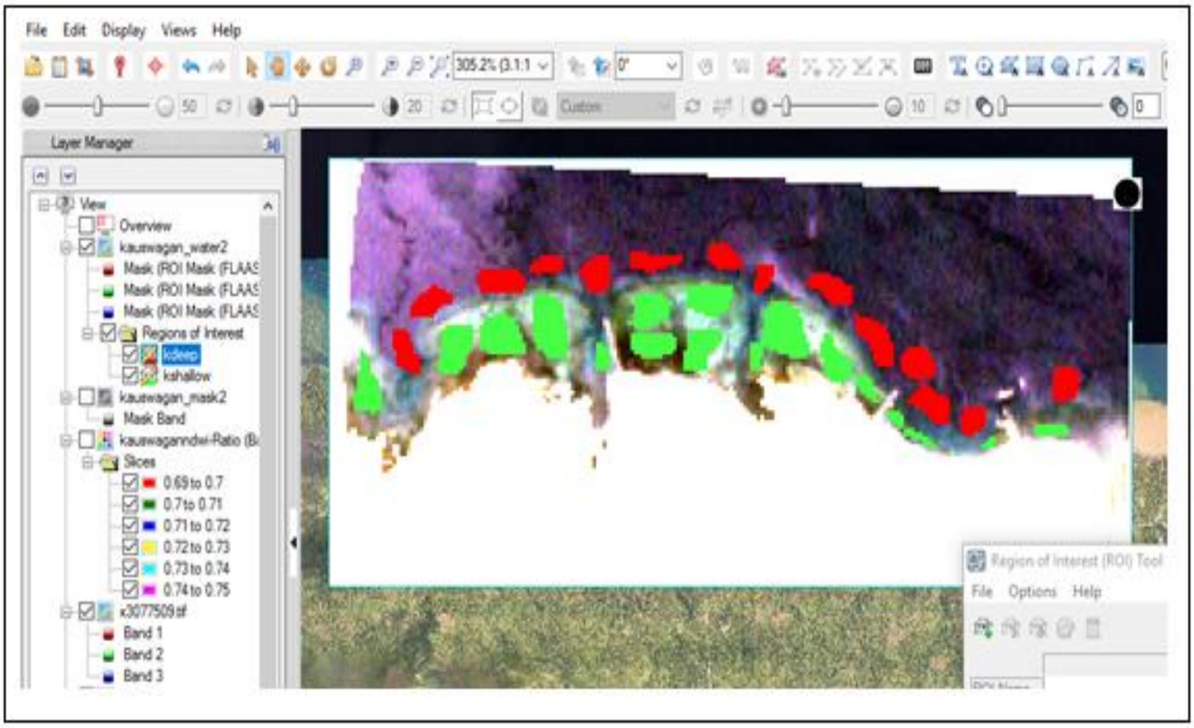

Fig. 7. Resizing and masking of deep and shallow regions of the map of Kauswagan, Lanao del Norte.

Class Confusion Matrix

File

Confusion Matrix: C:\Users\Windows 10\Desktop\landsatprocess\apriledited1

Overall Accuracy = (36/40) 90.0000%

Kappa Coefficient = 0.8507

Ground Truth (Pixels)

Class	foreditvp23me	foreditvp23me	foreditvp23me	foreditvp23me	Total
Unclassified	0	0	0	0	0
mTPK [Name=Al	7	0	0	1	8
mTPK [Name=Co	0	17	0	1	18
mTPK [Name=Sa	0	0	3	0	3
mTPK [Name=Se	0	2	0	9	11
Total	7	19	3	11	40

Ground Truth (Percent)

Class	foreditvp23me	foreditvp23me	foreditvp23me	foreditvp23me	Total
Unclassified	0.00	0.00	0.00	0.00	0.00
mTPK [Name=Al	100.00	0.00	0.00	9.09	20.00
mTPK [Name=Co	0.00	89.47	0.00	9.09	45.00
mTPK [Name=Sa	0.00	0.00	100.00	0.00	7.50
mTPK [Name=Se	0.00	10.53	0.00	81.82	27.50
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
mTPK [Name=Al	12.50	0.00	1/8	0/7
mTPK [Name=Co	5.56	10.53	1/18	2/19
mTPK [Name=Sa	0.00	0.00	0/3	0/3
mTPK [Name=Se	18.18	18.18	2/11	2/11

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
mTPK [Name=Al	100.00	87.50	7/7	7/8
mTPK [Name=Co	89.47	94.44	17/19	17/18
mTPK [Name=Sa	100.00	100.00	3/3	3/3
mTPK [Name=Se	81.82	81.82	9/11	9/11

Fig. 8. Confussion matrix for Kauswagan, Lanao del Norte.

The high abundance of *Thalassia hemprichii* is due to its presence throughout the study areas. Considered as a climax species in the Indo-Pacific region (den Hartog, 1970; Lacap *et al.*, 2002; Short *et al.*, 2010) and when present in mixed sea grass meadows it usually dominates over the other sea grass species (Meñez *et al.,* 1983).

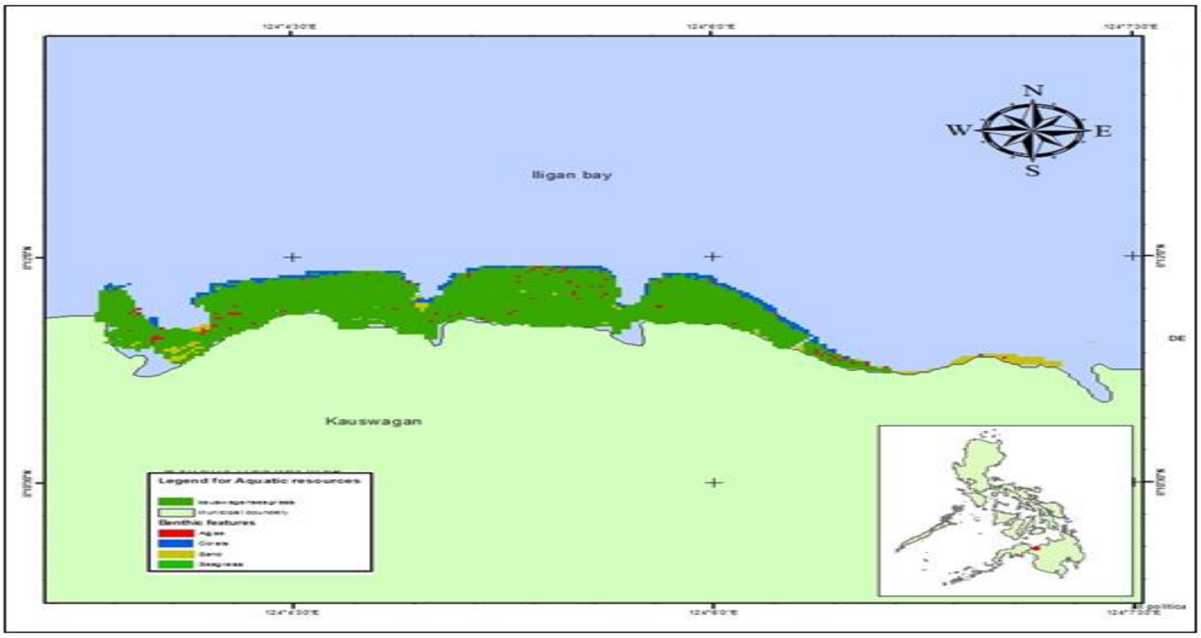

Fig. 9. Coastal resource map of Kauwagan, Lanao del Norte.

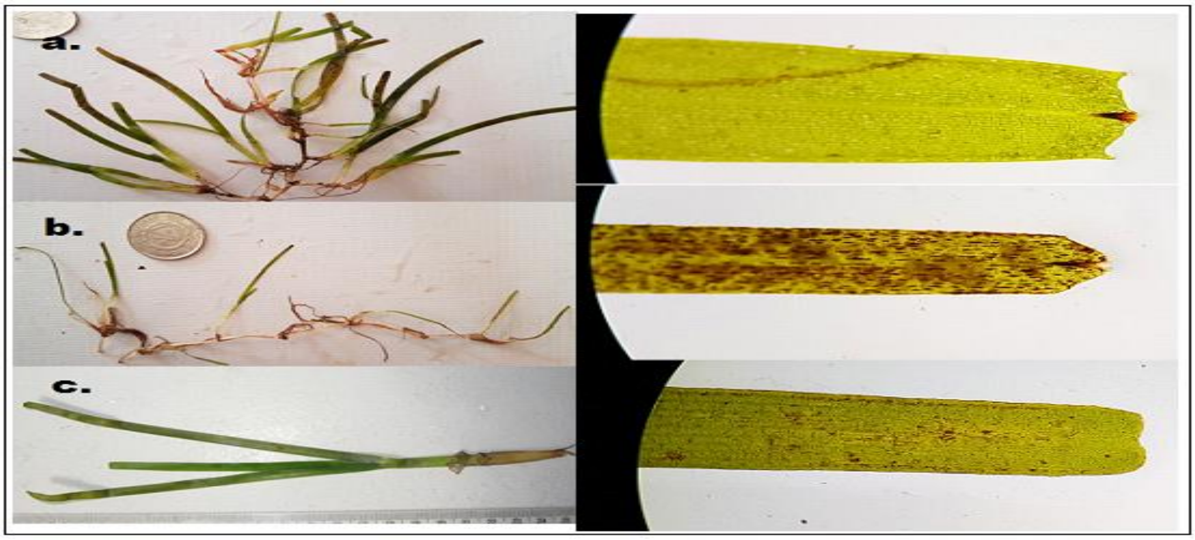

Fig. 10. Seagrass under Family Potamogetonaceae: a. *Haladule uninervis*, *b. Haladule pinifolia, c. Cymodocea rotundata.*

It was noted that thick mats of green algae were present in the areas and somewhat covered parts of the sea grass bed; now Fortes (1990) discussed that during summer months anoxia occurs due to rise of temperatures and low tidal conditions thus resulting to green algae proliferation.

It was studied that *Thalassia hemprichii* even under algal blooms can grow and develop optimally thus it can successfully colonize sea grass beds than other species one factor for its resilience is its root system and its adaptability to the low concentrations of light during algal blooms (Dy *et al.*, 2005).

Sea grass condition

The criteria used to assess the sea grass condition in this study is by Fortes (1989) using the percent cover estimates of each station.

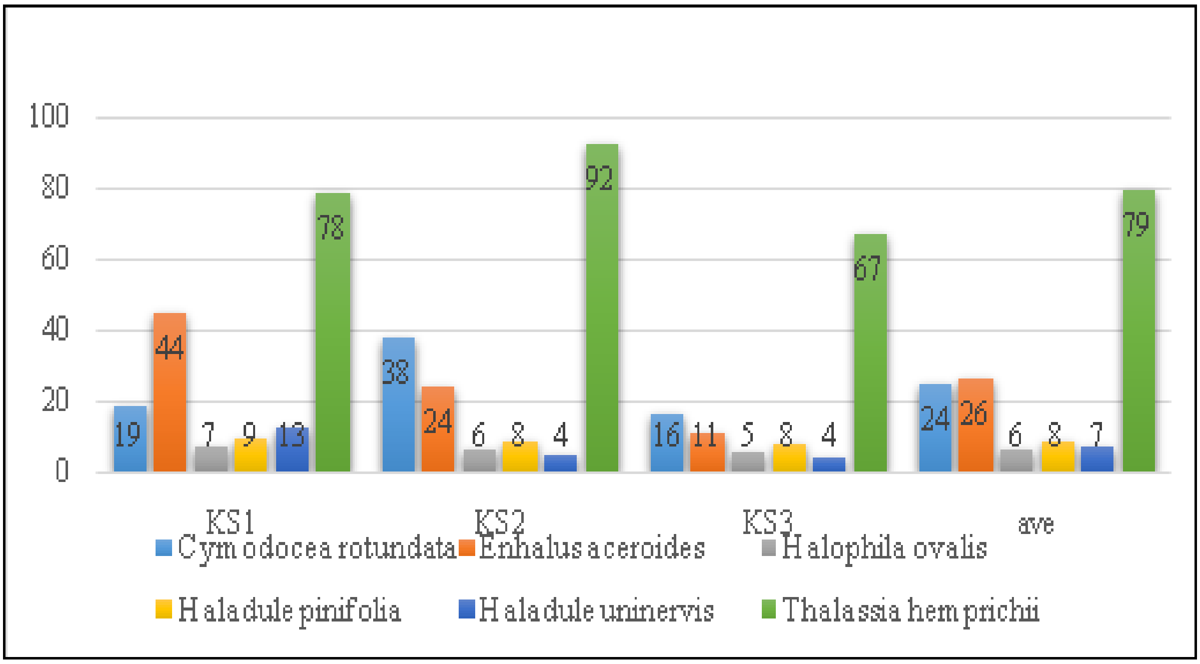

Fig. 12. Percent cover per station in Kauswagan, Lanao del Norte.

The average cover for Tacub is 68 % the seagrass cover of the municipality was considered in good condition (Table 5). Sea grass abundance in both study areas maybe contributed to the absence of industries and development; controlled physical and chemical disturbances in the areas due to presence of mangrove protected sites in each municipality and the strict implementation against destructive fishing practices.

In a similar study of Ame and Ayson (2009) in the northern Philippines the sea grass condition were Fair – Good in the 4 coastal municipalities. Compared to the study of the coastal areas in Iligan City by Orbita and Gumban (2013) the condition of Tacub was better than the Poor – Fair recorded condition.

In barangay Tacub both station 1 and Station 2 the first 2 stations were in excellent condition and Station 3 was the lowest but still under good condition. With the upcoming operation of the power coal plant near station 3 monitoring should be implemented.

Sea grass diversity

Seagrass density derived in this study was used to determine the species diversity indexes for each station. Diversity indexes such as Shannon-Weiner (H'), Evenness (E) and Simpson's index (D). Tacub has a shannon diversity index of 1.43; per station it ranges from 1.33 -1.54;station 1 had the highest value of 1.54, indicating that out of the 3 stations seagrass diversity is high while the second station had 1.33 indicating low diversity.

The Shannon index values indicates that the stability of sea grass is in "medium" range, it's possible that the stability of sea grass in the area has been undergoing ecological pressures like the study in Indonesia (Herawati *etal.*, 2016). Compared to the study of sea grass in Haganoy, Davao with an average H' = 0.31 (Jumawan *et al.*, 2015) the diversity in this study higher. Evenness (E) in the area was 0.70, indicating that the seagrass diversity in has a high value of uniformity. Dominance values of 0.31 indicates that for seagrass diversity no species is dominant.

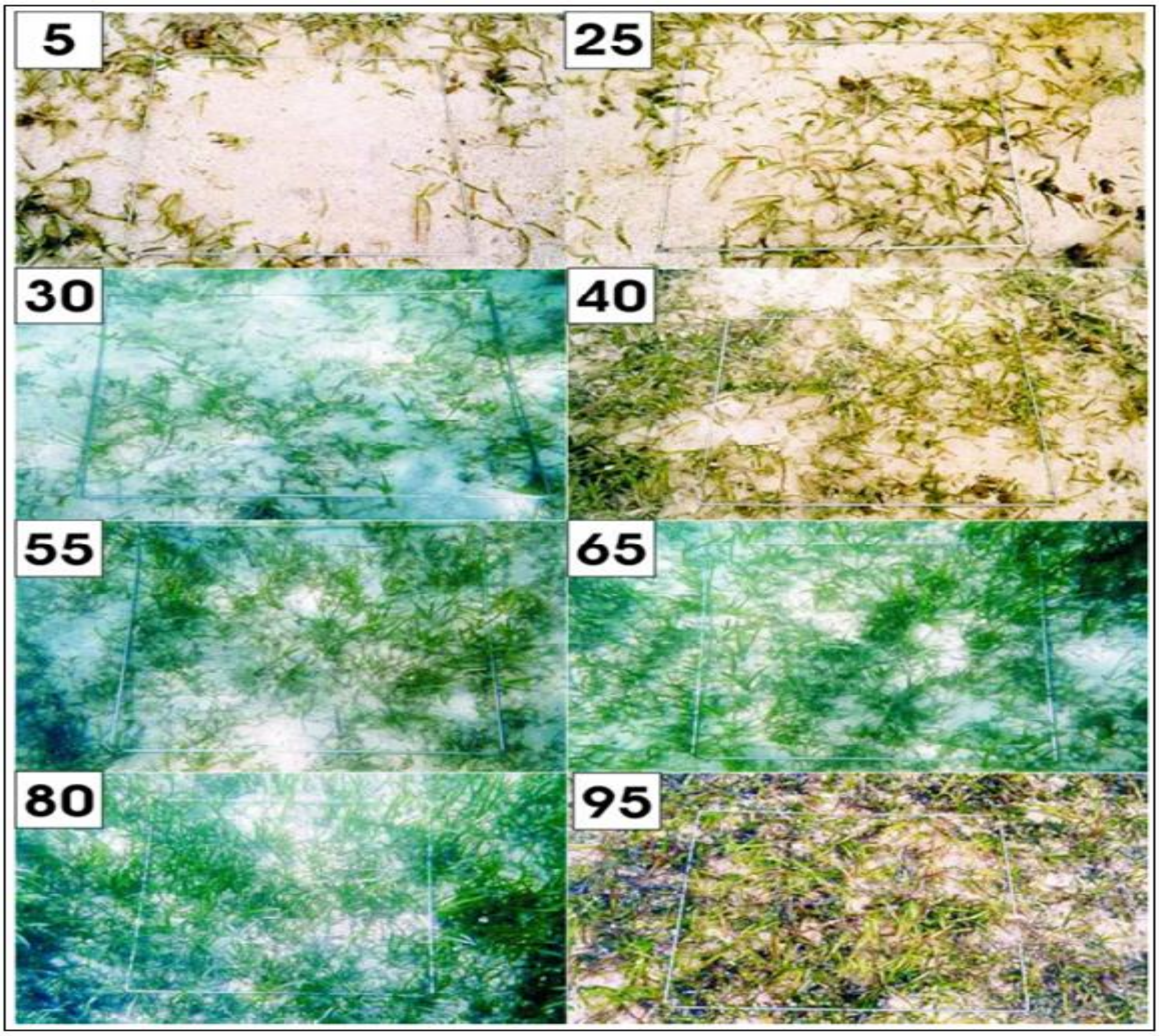

Fig. 13. Percent cover estimate sample.

Conclusion

The distribution of seagrass and other resources in Kauswagan were mapped using remote sensing in the form of Landsat and GIS. The total area of resources mapped in Kauswagan is 199 hectares. Sea grass dominated the coastal area with 183 hectares in Kauswagan. Softwares such as Arcmap and ENVI were used to further enhance the quality of the resources distribution for each barangays municipality. The accuracy of the map of Kauswgan is 90%.

A total of six (6) species of seagrass were observed in the coastal areas of barangay Tacub, Kauswagan Lana del Norte. The species represented by *Thallasia hemprichii, Cymodocea rotundata, Haladule uninervis, Enhalus aceroides, Halophila ovalis* and *Haladule pinifolia* constitute the vast intertidal zones where seagrass meadows support a variety of organisms from echinoderms to fishes. The most abundant seagrass in terms of cover and density is the species Thallasia hemprichii with a percent cover of 79% cover with a shoot density of 1021 shoots/m^2. The seagrass condition was assessed using percent covers that was based on Fortes' criteria; seagrass condition in was considered good despite the anthropogenic pressures present in the area such as pollution and the effects of gleaning. In terms of diversity the area had a shannon diversity index of 1.43.

It was noted that thick mats of green algae were present in the areas and somewhat covered parts of the sea grass bed; now Fortes (1990) discussed that during summer months anoxia occurs due to rise of temperatures and low tidal conditions thus resulting to green algae proliferation.

Algal blooms could be an indicator also of the presence of eutrophication that naturally is caused by the increase of nutrients in the water such as nitrates and phosphates but can dramatically increase because of anthropogenic factors such as siltation and pollution. Garbage accumulation was observed in this study especially garbage accumulation in the nipa and mangrove areas where if tides come will be transferred to the sea and some garbage settle in the sea grass areas preventing the growth of sea grass, it can possibly affected the algae blooms so further study and correlation for phosphate and nitrate must be done. By mapping and assessing seagrass meadows in Bacolod and Kauswagan Lanao del Norte this study will serve as a baseline data, that can be compared to changes towards the possible effects of the coal plant that is undergoing construction.

Acknowledgements

The Author would like to extend her gratitude to the Department of Science and Technology (DOST) for the funding of the study , Simmons Consult international for the field assistance and to Phil-LiDAR 2 Project of Mindanao State University – Iligan Institute of Technology for the technical assistance and training.

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