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Study of organic carbon (OC), and calcium carbonate ($CaCO_3$) in the coastal area of Aceh Besar

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ABSTRACT

Most of the coastal areas of Aceh Besar are areas of accumulation of organic compounds, one of which is Organic Carbon (OC). The purpose of this study was to analyze the chemical content by looking vertically at the content of OC, soil pH and Calcium Carbonate ($CaCO_3$) on the coast of Aceh Besar District. Analysis of the OC content using the Walkley and Black method, while to analyze the Calcium Carbonate ($CaCO_3$) using the Titrimetric method. Especially for the analysis of soil pH, only use a pH meter. The results showed that each station had different levels of OC and carbonate. Generally, the presence of OC decreases with depth, while the carbonate content varies. Especially for soil pH, the pH is relative to the alkaline state for each depth. The range of OC content for all stations is 0.18 – 2.48%, Carbonate 5.36 – 13.27% and pH 6.37-8.73.

Introduction

The coastal area of Aceh is divided into 18 districts or cities, one of which includes the coastal area of Aceh Besar District. Geographically, the coastal area of Aceh Besar Regency is located at a position of 5.2º - 5.8º North Latitude and 95.0º - 95.8º East Longitude (BPS, 2015). Aceh Besar district has an area of 2903.50 km^2, most of its territory is on the mainland and a small part is in the islands. Aceh Besar is bordered by the Malacca Strait and the Indian Ocean (BPS, 2014). The coastal area of Aceh Besar is bordered by land and sea. This area is rich in accumulation of OC and Carbonate ($CaCO_3$). Therefore, judging from such a location, the coastal areas especially on these cliffs are heavily influenced by processes on land and at sea (Susiloningtyas *et al.*, 2017).

Most of the coastal areas of Aceh Besar are areas of accumulation of organic compounds, one of which is OC (Fajrina *et al.*, 2019). Latifah *et al.* (2013) said that OC easily accumulates into finer materials such as clay and silt. OC on the coast has an effective role in the carbon cycle that links the carbon found on land with carbon in the sea (Baum *et al.*, 2007). According to Yang *et al.* (2007), that the presence of OC in coastal areas is due to coastal currents, water dissolution, human activities and fine grains. Although coastal areas occupy only 0.2% of sea level, they account for 50% of the total amount of carbon buried in sediments (Duarte *et al.*, 2013; Macreadie *et al.*, 2017).

OC is not only an important component of coastal areas but also plays an important role in regulating carbon storage, key productivity of coastal ecosystems and global climate change, thus carbon change has become one of the most important issues for sustainable coastal development (Bronson *et al.*, 2004). Shepherd (2011) suggested that the entry of carbon into the soil structure in coastal areas in general is because most of the soil (sediment) is in anaerobic conditions (without oxygen) so that the

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process of decomposition of carbon that enters the soil occurs very weakly and slowly. Carbon in these coastal areas can be stored continuously over long periods of time up to hundreds of years (Titiz and Sanford, 2007).

Other activities carried out on the coast of Aceh Besar besides providing changes such as OC and soil pH are chemical compounds ($CaCO_3$) or Calcium Carbonate. The coastal area of Aceh Besar is an area that contains calcium carbonate. Calcium Carbonate ($CaCO_3$) is also an important chemical compound that can determine the source of life in coastal areas. Increased concentrations of carbon dioxide (CO_2) in the atmosphere and increased nutrient input to coastal waters, can be directly linked to human activities (D'Angelo and Wiedenmann, 2014; Davidson *et al.*, 2014). The increase in CO_2 is predicted to have a deleterious effect on the biogeochemical cycle of calcium carbonate ($CaCO_3$) in coastal ecosystems (Glynn and Manzello, 2015). $CaCO_3$ compounds are fundamental materials that can show interesting properties in different forms, states and origins of $CaCO_3$. Historically, Veron (2008) stated that sedimentary $CaCO_3$ in coastal areas has served as a chemical buffer for previous seawater acidification events when atmospheric CO_2 increased sharply due to volcanic eruptions. Research on Calcium Carbonate ($CaCO_3$) on the coast was previously reported by Sulistiyono (2017) in Sumenep Regency. The results of the study show that carbonates from the northern coastal area of Sumenep Regency lead to calcium rocks compared to magnesium so that they are directed to the calcium carbonate precipitate industry.

A case study in Southeast Alaska, United States of America was conducted by Walinsky *et al.* (2009) regarding OC where the results obtained are very high total organic carbon and biogenic silica (opal) content, which contain 8% and 33% by weight, respectively. Still in the United States, research on the dynamics of organic carbon has been carried out by Duan *et al.* (2015) on the Maryland's coast. The results show that the organic carbon concentration on the coast of 187-501 μM is comparable to the eutrophic coastal waters of the United States but higher than the Mid-Atlantic Bight. Sempere *et al.* (2002) also conducted research on the organic carbon concentration in the Aegean Sea using the high-temperature catalytic oxidation method. The results showed that the OC concentration decreased from surface to deep water from 52–128 to 48–56 μM C in the North and from 55–87 to 47–56 μM C in the South.

Permanawati and Hernawan (2018) conducted a study on OC and carbonate in Indonesia in the waters of Lembata, Flores Sea. The results of the study showed that the percentage of $CaCO_3$ (carbonate) was 16.3-79.9% and OC was 0.99-4.45%. The OC circulation indicates a dynamic alteration in the central waters area compared to the eastern and western areas. In addition, Hakim (2015) has also conducted research in the waters of Pulau Tikus, Bengkulu the results obtained that the shape of sediment grains has a negative relationship to the OC content. Research in the waters of the Belitung Sea has also been carried out by Putri *et al.* (2015), the results of the study show that the distribution of OC in the soil (sediment) has the highest content of 12.05% while the range of total organic carbon concentration in sediment is 0.78% - 12.05%. For the study of OC in Aceh Besar, Ghafar *et al.* (2018) in the mountains of Deudap, Pulo Aceh. The results showed that the overall soil carbon content in 8 stations obtained the highest total soil carbon content, namely at station 5 with a total carbon content of 155.8 g/cm^2, while the lowest total carbon content was at station 3 with a total carbon content of 0.43 g/cm^2.

The study of OC and carbonate ($CaCO_3$) in the Coastal area of Aceh Besar based on the above description is a study that only focuses on chemical conditions on the coast. This study is still very poorly done and becomes an interesting object to be investigated specifically in this area. Therefore, studies on OC, salinity, soil pH, temperature, and $CaCO_3$ focusing on the coast need to be carried out. The study of OC in coastal areas is currently receiving attention not only because it is related to coastal areas, but also because of the absorption of organic carbon in the soil to reduce carbon dioxide emissions. Studies of OC and carbonate ($CaCO_3$) on the coast of Aceh Besar are still very limited, so it is necessary to conduct research on OC and carbonate in coastal areas globally.

Materials and Methods

This research is not only a literature study on three parameters of chemical analysis, namely OC, soil pH and Calcium Carbonate ($CaCO_3$) but also field sampling data from study site which is later on analyzed in the laboratories.

Research location and time

This research was conducted in the coastal cliff area of Aceh Besar Regency. Determination of the station there are 4 points, which can represent areas that have different characteristics. The sampling locations were in the areas of Ujong Batee Puteh,

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Lamreh, Ujong Pancu, and Lhokseudu. This research was conducted by taking samples of sediment (soil) in the field and laboratory tests. This research was conducted in June – August 2021 and the research location can be seen in (Figure 1). Chemical analysis of OC and Calcium Carbonate ($CaCO_3$) was carried out at the Research and Industrial Standardization Center (Baristand) Banda Aceh and the Soil Chemistry Laboratory, Faculty of Agriculture, Syiah Kuala University.

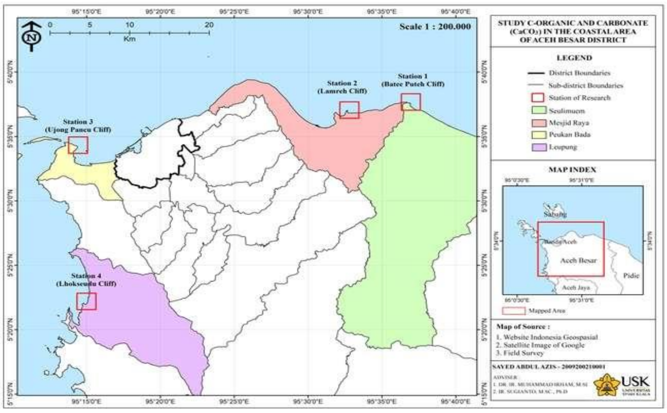

Figure 1. Research Location (Source: Google Earth, 2022).

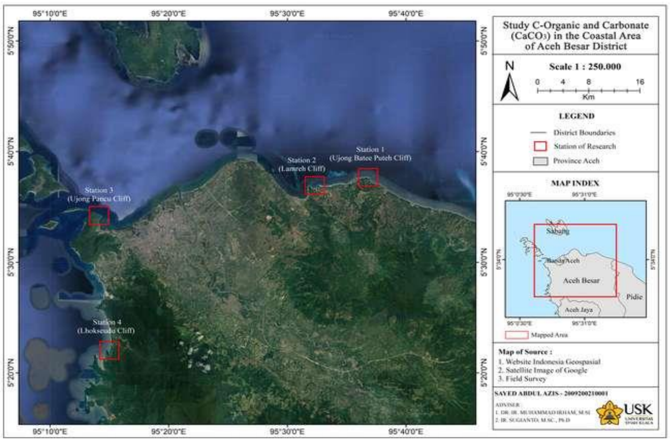

Figure 2. Chemical parameter distribution map.

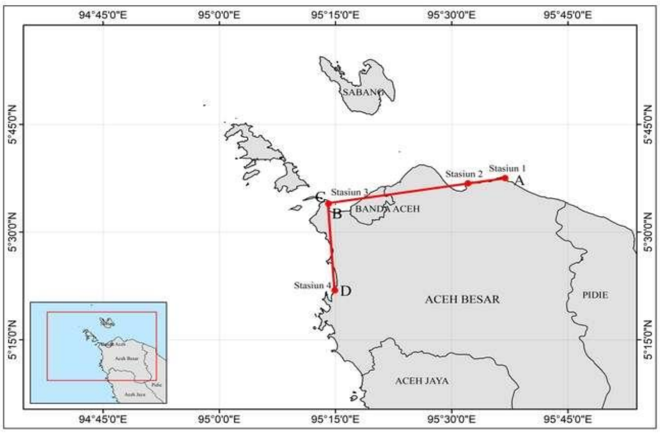

Figure 3. Cross-Sectional map in the coastal area of Aceh Besar.

Figure 4. Batee puteh cliff sampling point.

Figure 5. Lamreh cliff sampling point.

Figure 6. Ujong Pancu cliff sampling point.

Data analysis

Soil or sediment samples were taken to the Research Center and Industrial Standardization (Baristand) Laboratory and Soil Chemistry Laboratory, Faculty of Agriculture, Syiah Kuala University. The data obtained from the laboratory results are described quantitatively. The tools and materials used in this study can be seen in Table 1.

Figure 7. Lhokseudu cliff sampling point.

Table 1. Research tools and materials.

Tools and Materials	Specification
Global Positioning System (GPS)	Garmin
Hand Auger	75 mm x 1 meter
Thermometer	Lammote
Conductivity	Chemtrix Type 700
pH Meter	Luthron PH-212
Shaker Machine	Gerhardt Schuttelmaschine LS 20
Digital Schales	Matrix DJ303A
Burette 50 ml	Pyrex
Erlenmeyer 250 ml	Pyrex
Shake Bottle 50 ml	Plastik PE-LD
Pipette Volume 5 ml	Pyrex
Pipette Volume 10 ml	Pyrex
Watch Glass	Rofa
Measuring Cup 100 ml	Pyrex
Camera	Vivo
Ruler	Butterfly
Plastic Bag	Legenda HDPE
Gloves	Luto

Sampling of OC, Soil pH and $CaCO_3$

Soil sampling of OC, soil pH and $CaCO_3$ was carried out using the coring method (ASTM, 2008), with a depth of 1 meter perpendicularly using a Hand Auger tool. Samples were taken 5 samples at each research station. Sediment sampling was taken successively from the top layer to the bottom layer with a depth interval of 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm. Sediment sampling was carried out at each sampling point. Each sample is marked with a permanent marker written on a plastic bag. Soil samples that have been taken were taken to the Laboratory of Research and Industrial Standardization Center (Baristand) Banda Aceh and the Laboratory of Soil Chemistry for identification.

Analysis of OC

Analysis of the OC content was carried out using the Walkley and Black method. The working procedure for analyzing the OC content is as follows: In the first stage, the samples were dried in a soil drying laboratory for 11 hours with a room temperature of 32°C-33°C. The second stage, weighing 0.500 g of soil samples with a size of <0.5 mm, then the samples were put into a 250 ml Erlenmenyer. The third step is to add a solution of 5 ml of $K_2Cr_2O_7$ 1 N then add it again using a solution of 10 ml of concentrated H_2SO_4, then stir and then let it sit for 30 minutes. The next step, after being allowed to stand, add 100 ml of distilled water, then add 5 ml of phosphate (H_3PO_4) solution. The last stage of the analysis of the OC content is to add 1.5 ml blank solution and titrate using $FeSO_4$ solution until the color changes.

Soil pH analysis

The working procedure for soil pH analysis is as follows: the first step, weighing a sample of 10.00 g of soil sample using a digital scale. The second stage, after weighing the sample, put it in a shaker bottle, then add 25 ml of ion-free water. Then, it was shaken with a shaker machine for 60 minutes. The last step is to measure the pH content of the soil using a calibrated pH meter. Every time the calibration is carried out, washing and drying is carried out with a tissue.

Calcium Carbonate ($CaCO_3$) analysis

Analysis of soil $CaCO_3$ content was carried out using the Titrimetric method. The reagents used are HCL, PP indicator, and NaOH. The working procedure in analyzing the content of Calcium Carbonate ($CaCO_3$) is: The first stage, the soil sample is weighed 1 gram using a digital scale, after weighing the sample is placed in a watch glass (watch glass). The second stage, the sample is put into a 250 ml erlenmeyer. In the third step, 25 ml of distilled water was added and then 15 ml of 0.5 N HCL was added. The last stage of the analysis of the $CaCO_3$ content, the previously mixed solution was heated after cooling, HCL was titrated using 0.1 N NaOH solution with PP indicator until it turned pink.

Results

Laboratory test results for OC, pH, salinity, and carbonate parameters can be seen in Table 2 for station 1, Table 3 for station 2, Table 4 for station 3, and Table 5 for station 4. OC and carbonate are different. Generally the presence of OC and salinity decreases with depth, while the carbonate content varies. Especially for soil pH, laboratory test results are relatively the same for each depth. The range of

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OC content for all stations is 0.18 – 2.48%, Carbonate 5.36 – 13.27%, pH is relative to the alkaline state.

Table 2. Parameters of OC, pH, and $CaCO_3$ at Station 1, Ujong Batee Puteh area.

Depth	OC (%)	Soil pH	$CaCO_3$ (%)
Depth 1 (20 cm)	1,70	8,08	5,36
Depth 2 (40 cm)	2,48	8,02	5,89
Depth 3 (60 cm)	0,78	8,22	11,72
Depth 4 (80 cm)	0,72	8,32	13,27
Depth 5 (100 cm)	0,58	8,39	12,16

Table 3. Parameters of OC, pH, and $CaCO_3$ at Station 2, Lamreh area.

Depth	OC (%)	Soil pH	$CaCO_3$ (%)
Depth 1 (20 cm)	0,70	8,36	9,29
Depth 2 (40 cm)	1,03	8,37	12,40
Depth 3 (60 cm)	0,40	8,58	12,56
Depth 4 (80 cm)	0,18	8,73	8,31
Depth 5 (100 cm)	0,22	8,61	12,82

Table 4. Parameters of OC, pH, and $CaCO_3$ at Station 3, Ujong Pancu area.

Depth	OC (%)	Soil pH	$CaCO_3$ (%)
Depth 1 (20 cm)	1,73	6,76	12,89
Depth 2 (40 cm)	0,93	6,40	11,55
Depth 3 (60 cm)	0,76	7,12	6,11
Depth 4 (80 cm)	0,57	6,91	5,87
Depth 5 (100 cm)	0,31	7,04	6,77

Table 5. Parameters of OC, pH, and $CaCO_3$ at Station 4, Lhokseudu area.

Depth	OC (%)	Soil pH	$CaCO_3$ (%)
Depth 1 (20 cm)	2,39	7,35	10,67
Depth 2 (40 cm)	1,18	6,73	11,80
Depth 3 (60 cm)	0,85	6,74	10,95
Depth 4 (80 cm)	0,86	6,37	11,86
Depth 5 (100 cm)	0,45	6,67	8,09

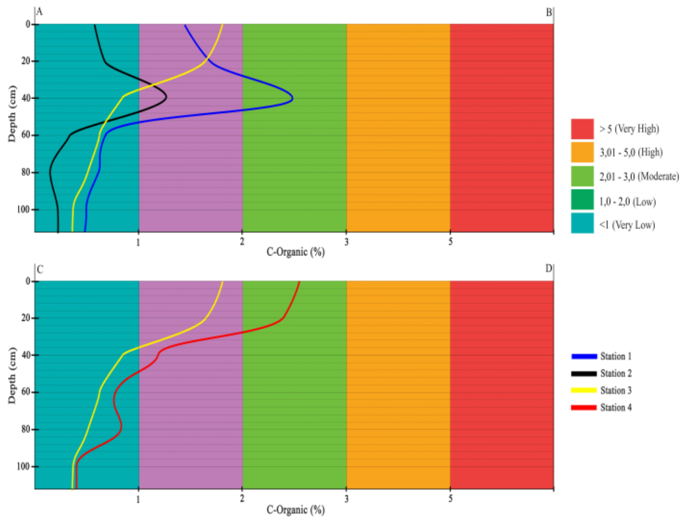

Figure 8. Cross-sectional map of OC to depth.

Discussion

Distribution of OC to depth

The content of OC in the soil (sediment) can reflect the quality of the soil. Distribution of OC to depth in the Coastal area of Aceh Besar Regency is important to determine environmental conditions that affect the state of organic matter. The results of the cross-sectional analysis for the distribution of OC to depth at each station in the study area can be seen in (Figure 8). These results indicate whether there is a significant correlation and difference in OC content from each tested station.

The cross-sectional map of the OC parameter to the depth at each station in the study area can be seen in Figure 8. The figure shows that the OC distribution at station 1 has a large OC composition in the 1st layer to the 2nd layer which has increased which then decreases and tends to be steady (stagnant) with depth. Station 2 has a large OC content only in layer 2, then it decreases and tends to be steady (stagnant). Stations 3 and 4, the largest composition of OC is only in the 1st layer and so on it decreases with depth.

The composition of OC in all stations in the Coastal area of Aceh Besar shows a low value. This is in accordance with (Sufardi *et al.*, 2020) which states that the OC content of soil in tropical climates is generally low, because soil organic matter will quickly mineralize so that OC content is easily lost. The OC content at station 1 was more influenced by leaf litter, due to leaf litter accumulating on the surface and below the soil surface (Turner and Lambert, 2000). It is different at station 2, OC is affected by the erosion process. Soil erosion washes away nutrients and organic carbon in the upper layers, reducing productivity in the region (Olson *et al.*, 2015). Stations 3 and 4, OC on the surface is affected by vegetation. The distribution of vegetation is closely related to environmental heterogeneity and organic carbon (Arellano *et al.*, 2017). Soil properties vary with soil depth, and the variability is often higher at 0-20 cm depth than in the subsoil (Yemefack *et al.*, 2006).

The study of this research shows that the value of OC decreases with increasing depth. Previous studies by Sufardi *et al.* (2020) on dry land in Aceh Besar District showed that changes in OC content according to soil depth in all soil orders were the same, namely decreasing with increasing depth. Fajrina *et al.* (2019) states the same thing for the case study in the Jantho area, that the composition of C-Oganic decreases as the depth of sediment (soil) increases. Research Donato *et al.* (2012) showed that the largest OC was at the top of the soil layer, then the value decreased at depths below one meter. On the other hand, Dung *et al.* (2016) also reported a small amount of OC in the top soil layer at the forest edge of Can Gio Mangrove Park, Vietnam and there was a decrease in OC from a depth of 0-100 cm and then stabilized at a layer of 100-250 cm.

Several factors can affect OC to soil depth such as: soil properties (soil texture, pH), climate (temperature and rainfall), soil parent material, topography, and anthropogenicity, including land use and management, human input (fertilizers). (Stockmann *et al.*, 2013; Wiesmeier *et al.*, 2015). Carbon content will tend to decrease due to a decrease in the supply of surface litter with increasing soil depth (Nguyen, 2003).

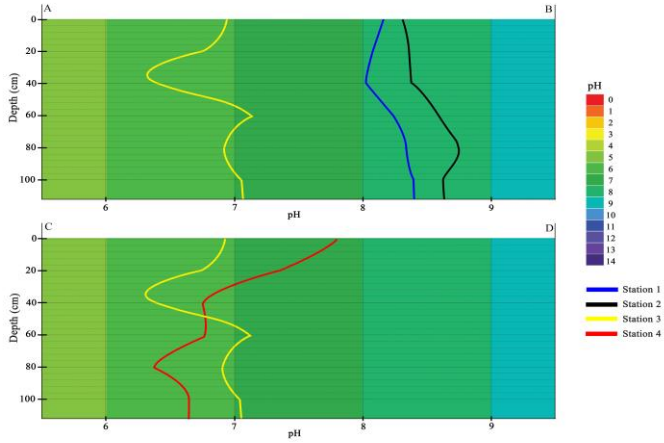

Figure 9. Cross-sectional map of soil pH to depth

Distribution soil pH of to depth

The distribution of soil pH to depth in the Coastal area of Aceh Besar Regency is important to determine the environmental conditions that affect the acidity of the soil. The results of the cross-sectional analysis for the distribution of soil pH to depth at each station in the study area can be seen in (Figure 9). These results indicate whether there is a correlation between each station being tested.

Figure 9 shows that the distribution of soil pH at stations 1 and 2 has the same pattern with a pH value between 8.02-8.73, this result indicates that the soil is neutral to alkaline in that area. This is different from stations 3 and 4 with a pH value between 6.37-7.35, where the pH composition of the soil indicates that in that area the soil is acidic towards neutral. The difference in soil pH in all stations is caused by composition which depends on the depositional environment experienced by the area (Balstrom *et al.*, 2013). Therefore, each depositional environment has a settling period (time required for sediment to settle) which also depends on the environment when the deposition process occurred (Jeong *et al.*, 2022). Differences in depositional time and depositional environment also cause differences in soil acidity per depth.

Soil with a pH value towards alkaline at stations 1 and 2 can be caused by the influence of the coast, especially the carbonate depositional environment which contains a lot of lime (Lapietra *et al.*, 2022). Lime is one of the compounds that can cause sediment or soil to become alkaline, however, in an acidic environment, lime can neutralize soil properties in that environment (Kowalska *et al.*, 2019; Bohlenius *et al.*, 2020). The results of the analysis of soil surface pH at station 3 have a low value (towards acid) caused by the decay of organic matter such as plants and the soil sediment environment. Zhang *et al.* (2017) stated that the acidic nature of the surface soil layer was most likely caused by the decomposition of organic matter in high quantities, the release of organic acids by the decay being absorbed by the soil. At a depth of 0-100 cm, station 1 and station 2 have an alkaline pH, while stations 3 and 4 have an acidic pH. This can be caused by microorganisms that live at these depths which are able to rapidly remodel the litter according to the rate of litter decomposition (Saibi, 2017) where this rate will decrease if the acidity is increased. Other factors affecting soil pH include: climate, soil depth, rainfall, vegetation, and agricultural activities (Ou *et al.*, 2017). Brady and Weil (2014) report that rainfall in vegetation environments, tends to have a relatively low pH due to reduced saturation based on the loss of alkaline cations by leaching.

Soil pH values for all stations showed varying values ranging from 6.37 to 8.73. The resulting pH is ideal for the content of organic compounds, microorganisms, vegetation, nutrients and minerals in optimal conditions, so that the pH is included in the most ideal soil conditions for growth and availability of essential plant nutrients (Rousk *et al.*, 2009; Watson *et al.*, 2014).

Based on the cross-section of the distribution at (Figure 9) stations 1 and 2 show a pattern that the lower the pH of the soil, the more alkaline it is. This is because the station contains more lime and is generally found in coastal areas. In addition, alkaline soils also contain higher levels of magnesium, calcium, potassium, and sodium ions (Makungwe *et al.*, 2021). Stations 3 and 4 show a pattern that the lower the pH of the soil, the more acidic it is. This is because acidic soils have high hydrogen, aluminum and sulfur content (Jones, 2012). Under acidic conditions, plants are usually unable to grow properly because nutrients cannot be absorbed by plants optimally.

Martunis *et al.* (2017) conducted a case study in Aceh Besar by looking at the chemical characteristics of the soil in Aceh Besar District. The results showed that the chemical characteristics of the soil varied and the pH parameters of the soil were acidic and neutral in depth. The same thing was also done by Jummi *et al.* (2020) in Gampong Lamkeuneung, Aceh Besar District. The results of the study explain that the soil pH in the area is neutral (7).

Distribution $CaCO_3$ of to depth

The results of the cross-sectional analysis for the distribution of $CaCO_3$ to depth at each station in the study area can be seen in (Figure 10). These results indicate whether there is a correlation between each station being tested. Station 1 on the cross-sectional map is marked in blue, station 2 in black, station 3 in yellow and station 4 in red.

Figure 10 shows that the distribution of $CaCO_3$ at stations 1 and 3 has the largest content opposite, the largest station 1 from layer 3 to layer 4 has increased, while station 3 has the largest $CaCO_3$ content in layer 1 and decreased in the next layer stagnantly. Soil $CaCO_3$ content at stations 2 and 4 did not have a significant variation, this was due to an increase and decrease in the value of $CaCO_3$ in each layer based on the depth of the soil. Station 2 the largest content is in layer 2 to layer 3, and there is an increase again in layer 5. Another case at station 4, the largest content is in layer 2, then it decreases in layer 3 and then there is an increase in the value of $CaCO_3$ in layer to layer 4.

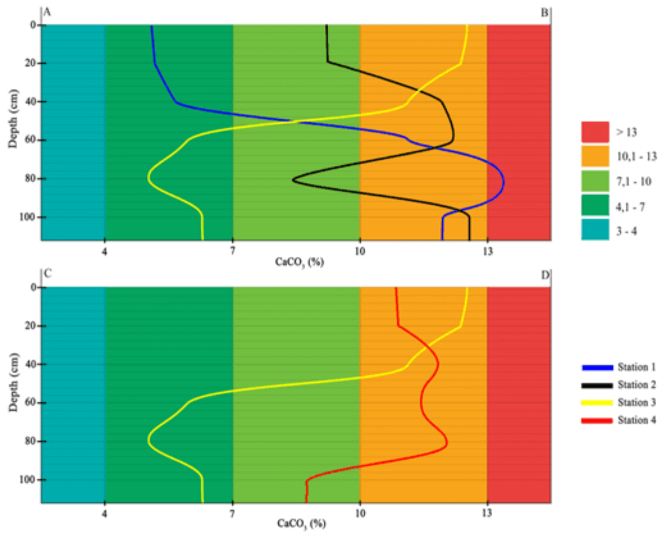

Figure 10. Cross-sectional Map of $CaCO_3$ to Depth

The soil carbonate ($CaCO_3$) value (Figure 8) showed that at station 1 $CaCO_3$ increased with depth. On the other hand, at station 3, as the depth increases, $CaCO_3$ begins to decrease. Soil $CaCO_3$ values at stations 2 and 4 were relatively stable, where there was an increase and decrease in $CaCO_3$ content in certain layers. At the landscape scale, the weathering of calcium carbonate ($CaCO_3$) is controlled by factors such as soil pH, temperature, rainfall, runoff, rock fractures, and vegetation (Kirstein *et al.*, 2016). Generally, the content of calcium carbonate is of high value in an area, the pH of the soil in that location will be alkaline. Wilford *et al.* (2015) suggested that a high calcium carbonate content will affect the pH value, where a high calcium carbonate will make the soil pH alkaline and a low calcium carbonate composition will make the soil pH in an area acidic.

Stations 1 and 2 in the study area indicate that the high $CaCO_3$ is due to the presence of carbonate rocks in their formation. Durand *et al.* (2007) suggested that the broad distribution of calcium carbonate-rich soils reflects the various processes that lead to their soil formation. This is supported by the statement of Ford and Williams (2007), carbonate rocks occupy about 10% of the world's soil surface and are important soil parent materials.

Conclusion

The content of OC and carbonate is different in each Aceh Besar Coastal station. The presence of OC decreases with depth, while the carbonate content varies. Research shows that the higher the OC, the lower the $CaCO_3$ and vice versa. The range of OC content for all stations is 0.18 – 2.48%, Carbonate 5.36 – 13.27%, and the pH is relatively alkaline.

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