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Course Project

Climate change is increasing the frequency and intensity of natural disasters, especially hurricanes and coastal flooding, which strongly influence coastal ecosystems. In South Florida, mangrove forests protect shorelines, support biodiversity, and store large amounts of carbon in their roots and soils. Hurricane Irma in 2017 caused major canopy loss, sediment changes, and disruptions to mangrove biogeochemistry. Understanding how storms like Irma affect mangrove health is important for predicting long-term resilience in a warming climate. This project tests the idea that mangrove height and total organic carbon (TOC%) collected after Irma will reflect storm impacts, meaning areas that were hit harder should show shorter mangroves and differences in soil carbon.

Research shows that extreme climate events such as hurricanes, storm surge, and rapid hydrologic change can significantly affect coastal vegetation and soil carbon. Lagomasino et al. (2021) documented widespread mangrove mortality caused by major hurricanes. Smith et al. (2009) found long-lasting changes in ecosystem metabolism and nutrient cycling after storm events in Florida Bay. Santos et al. (2025) projected that stronger future storms will increase stress on coastal wetlands and reduce carbon storage. Osland et al. (2020) showed that storm surge and salinity shifts can slow mangrove growth and alter belowground carbon inputs. Together, these studies suggest that hurricanes can reduce mangrove height and influence TOC%, which supports the idea that Irma likely impacted South Florida mangroves.

This project uses two datasets that combine field-measured mangrove height with laboratory-measured TOC% from two sites in South Florida (MD-1 and MD-3) sampled after Hurricane Irma. Mangrove height was collected using georeferenced GCPs, giving several measurements across each site. TOC% was measured from soil cores taken at consistent depth intervals, processed in the lab, and analyzed using mass spectrometry. MD-1 represents a disturbed site with clear mangrove dieback and many low or zero height values. MD-3 represents a healthier site with taller mangroves. These differences are important for interpreting any relationship between height and soil carbon. The mean of the mangrove height was 13.06571429, and the mean of the TOC was 3.53571429. The median of each were 4.865 and 3.1875, respectively. The standard deviation of each were 14.00408905 and 0.37404214, respectively

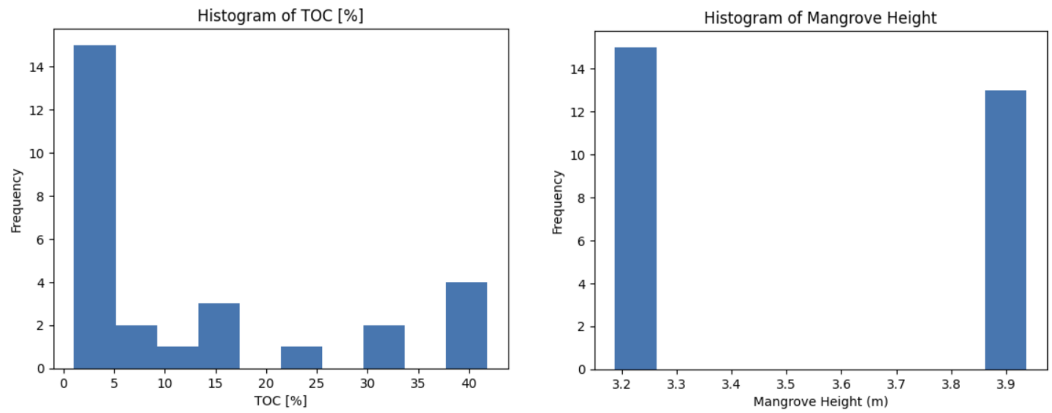

Figure 1. Two side-by-side histograms of mangrove height and TOC%.

Correlation analysis found a weak relationship between mangrove height and TOC%. Height values formed two tight groups that matched the site differences between MD-1 and MD-3, while TOC% values were much more variable and ranged from very low to extremely high. Pearson and Spearman correlations were both close to zero (Pearson: $r = 0.518$; $p = 0.0047$) (Spearman: $r = 0.638$; $p = 0.0003$), showing that height and TOC% do not meaningfully track each other at the sample level. This suggests that changes in canopy structure do not immediately translate into changes in soil carbon, at least at the depths and times sampled.

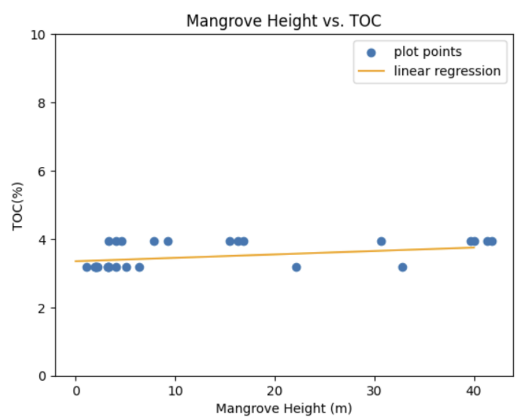

Figure 2. Scatter plot with regression line and correlation coefficients.

PCA was used to simplify the dataset and highlight major patterns in mangrove height and TOC%. Samples were color-coded by site because MD-1 and MD-3 experienced different levels of disturbance. The PCA plot shows strong separation between the two sites along PC1, which explains most of the variance. MD-1 clusters with low height and low TOC, while MD-3 clusters with higher values for both variables. PC2 captures smaller differences within sites. The loading plots show that height and TOC both contribute strongly to PC1, meaning the main pattern reflects the difference between the damaged MD-1 site and the healthier MD-3 site.

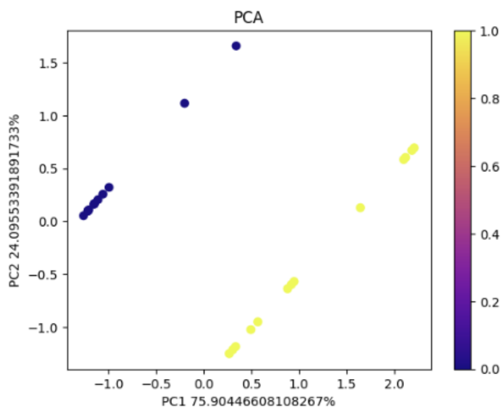

Figure 3. PCA plot.

From this analysis, I learned that mangrove height and TOC% show large differences between sites but only weak correlation within them. MD-1 had shorter mangroves and generally lower TOC%, while MD-3 had taller mangroves and higher TOC%. Because height and TOC% showed little connection within sites, the hypothesis that they track hurricane impact together is only partly supported. The results show clear site-level effects of Irma, but soil carbon responses may take longer to appear or vary more with depth. This suggests that assessing mangrove recovery requires more than just canopy height.

The study is limited by having only two sites, uneven sampling, and a single time point. Soil carbon also changes slowly and may be influenced by factors like salinity and sediment movement. Future work should sample more locations, include multiple time points, and add variables such as salinity, elevation, and root biomass to better understand how hurricanes affect both mangrove structure and soil carbon.

Bibliography

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Supplementary Figures