



CLUSTER TWO

PRODUCT DEVELOPMENT & TREND ANALYSIS

The flask illustrates the pivotal role of product development, particularly in conjunction with chemical experimentation. Adjacent to the flask orbits a satellite, symbolizing the expansive reach of data acquisition inherent in the field of product development. These symbols, along with the portrayal of space within our universe, suggest that the impact of studies centered on trend analysis and product development transcends the earth, giving emphasis on the significance of these disciplines in the field of research.

Cluster 2 is a compilation of research studies that address the development of new products and the trends of historical data. Studies under product development involve designing, creating, and testing a product's efficiency to be presented as an alternative to commercially available goods. Studies on trend analysis, on the other hand, examine the significant trends and changes in historical statistical data to provide valuable insights into how these aspects impacted various important geographic features in the country.

Assessment of lead concentration in surficial sediments of an island harbor estuary in Western Visayas, Philippines by flame atomic absorption spectrophotometry (FAAS)

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Article Info	Abstract
<p>Submitted: July 24, 2023 Approved: Dec 15, 2023 Published: Dec 31, 2023</p> <hr/> <p>Keywords: heavy metals anthropogenic activities lead contamination Sediment analysis Flame Atomic Absorption Spectrophotometry</p>	<p>Lead contamination is an emerging problem in the Philippines due to marine activities such as boating and commercial fishing in most coastal areas like MacArthur's Wharf in Guimaras. The aquatic environment's health is assessed by considering sediment quality through Flame Atomic Absorption Spectrophotometry (FAAS). Four surficial sediment samples were collected at 0 m, 25 m, 50 m, and 75 m away from the innermost sections of the docking area of the wharf, and the Pb concentrations were 23.66 ppm, 15.34 ± 1.07 ppm, 12.31 ± 1.07 ppm, and 11.80 ± 1.07 ppm, respectively. All samples fulfilled the permissible lead concentration in sediments by the National Oceanic and Atmospheric Administration (NOAA) at <30.24 ppm, and the U.S. Environmental Protection Agency (U.S. EPA) at <40 ppm, implying that MacArthur's Wharf, Guimaras, is within the acceptable environmental standards.</p>

Introduction. - Heavy metal (HM) contamination of aquatic ecosystems is developing into a possible global issue due to its hazardous impacts on the environment and public health [1]. Heavy metals are elements with high atomic weights and densities that pose a danger even at low concentrations [2]. In certain amounts, some play a vital role in the biochemistry and physiological functions of plants and animals but can be harmful to these organisms when exceeding the threshold value [2]. The study by Astatkie et al. (2021) [3] stated that surficial sediments may act as an adsorptive basin, especially for metals that exceed the threshold value and do not naturally degrade [4]. Thus, sediments are used as environmental indicators for the assessment of metal pollution in bodies of water [5].

All potential causes of sediment contamination with heavy metals include anthropogenic activities, such as dumping of domestic waste, drainage system inefficiencies, and natural occurrences like rock corrosion and weathering [3]. Lead (Pb) is a non-essential metal and one of the most hazardous and toxic contaminants in the environment [6]. It is largely found in the oil and gasoline industries [2,7]. One study on the analysis of the water column of Iloilo-Guimaras Port concluded that the exceeding amounts of Cd, Cr, and Pb could be mainly attributed to oil spillage from motor boats [16]. Shipping activities and marine traffic in ports reportedly have increased the flux of Pb into the marine environment [8].

In maintaining proper and balanced physiological functions in aquatic species, heavy metals play vital roles at trace levels or in small amounts [2,9]. Water bodies with excessive levels of heavy metals, however, harm aquatic life [2]. Later on, HMs like Pb could contribute to the long-term poisoning of the food chain [6]. Pb is found to be potentially carcinogenic to humans and animals, inducing damage to the brain, kidneys, liver, digestive system, endocrine system, and reproductive system [10].

One of the main wharves in Guimaras, MacArthur's Wharf, formerly known as "Buenavista Wharf," with coordinates of 10.6870° N, 122.6173° E, is located in the Iloilo Strait and is used to transport people, goods, and products to and from the island for industrial and commercial purposes, as well as to dock boats when they are not in use or require repair. Given their significance for international trade and economic activity, seaports have evolved into a coordinated land-sea region that is heavily influenced by human activity. Consequently, anthropogenic causes such as marine traffic, fishing, ship maintenance, and commercial activities may release pollutants into nearby seas and sediments. High Pb concentration in a port in Misamis Occidental was attributed to shipping and other anthropogenic activities in the area [10].

In addition, both residential and commercial buildings line the waterfront. According to the classification of water bodies and usage of marine waters of the Department of Environment and Natural Resources (DENR) Environmental Management Bureau, the surrounding waters of the



wharf are categorized as Class SC which includes fishery water, recreational water, and marshy and mangrove areas. It has beneficial uses including boating and the propagation of fish and other aquatic resources intended for commercial and sustenance fishing.



Figure 1. The docking area (encircled) of boats in MacArthur's Wharf, Guimaras

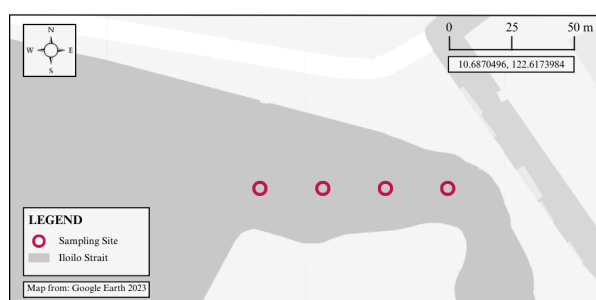


Figure 2. A close-up map of the docking area and the sampling sites (from Google Earth)

There are no sediment quality guidelines in the Philippines, but there are available standards developed by the National Oceanic and Atmospheric Administration (NOAA) [10], and the U.S. Environmental Protection Agency (U.S. EPA). Sediment Quality Guidelines (SQGs) are numerical chemical concentrations intended to be either protective of biological resources, predictive of adverse effects on those resources, or both. Heavy metal concentrations in the samples collected from the study area are assessed by comparing them with sets of SQGs. The study referred to two SQGs, the U.S. EPA and the NOAA Screening Quick Reference Table for Inorganics in Marine Sediment [11,12].

The investigation of heavy metals in surficial sediments is beneficial in assessing the anthropogenic and industrial impacts posed by pollution on water ecosystems. Heavy metals, like lead, are known to atomize with good efficiency with either N_2O or acetylene flame type with FAAS detection limits. A detector receives a light beam from a cathode lamp directed through the flame. The absorbed light is measured to compare with the light wavelengths that originally passed through the sample. The principle is that since the light beam has the same wavelength as the metal being observed, the absorbed light energy represents the concentration of the metal in the sample [13]. FAAS is also known for its low operational costs and good analytical performance. Therefore, in this study, surficial sediments were gathered in the docking

area of MacArthur's Wharf. Then, they underwent pretreatment and acid digestion before conducting the FAAS to determine the concentration levels of the heavy metal Pb.

The study aimed to determine Pb concentrations and its pollution and toxicity state in the surficial sediments of the docking area of MacArthur's Wharf, Buenavista, Guimaras with the following objectives:

- (i) To determine the concentration of Pb in the surficial sediments of MacArthur's Wharf, Buenavista, Guimaras by FAAS; and
- (ii) To assess the detected concentrations of Pb if it is within the permissible levels as set by the EPA Toxicity Classifications and the NOAA Screening Quick Reference Table for Inorganics in Marine Sediment.

Methods. - The study adopted a descriptive approach designed to assess whether the concentration of heavy metal Pb in the surficial sediments of the docking area of MacArthur's Wharf, Buenavista, Guimaras is within the permissible levels set by U.S. EPA and NOAA. The methodology is comprised of five parts: collection, pretreatment, digestion [14], preparation of the calibration curve, and FAAS analysis [15]. Surficial sediment samples were collected during the dry season from four separate sampling areas: 0 m, 25 m, 50 m, and 75 m from the innermost section of the docking area, the farthest that pump boats are stationed. The samples were then pretreated and digested before being analyzed through FAAS [14,16].

Collection of Sediment Samples. The collection of sediment samples was done in January during the dry season. Four sampling sites with 25-m intervals from end to end of the docking area of the wharf surrounded by residential areas were marked: 0 m, 25 m, 50 m, and 75 m. Around 500 g of the upper 5 cm surficial sediment layer of each marked collection area was collected with a separate plastic spoon for each area and transferred to a decontaminated zip lock bag. The sediment samples were then kept in a styrofoam box filled with ice while being transported to the Philippine Science High School - Western Visayas Campus (PSHS-WVC) laboratory.

Pretreatment of Sediment Samples. Upon arrival at the laboratory, the sediment samples were then oven-dried at $50^{\circ}C$ for 24 hours, grounded to ensure homogeneity, and sifted through a 3-mm sieve (or ASTM sieve size No. 16-8) to separate coarse-grained sediments and concentrate dust particles in this fraction that may contain high levels of heavy metal [14].

Acid Digestion. Acid digestion was then done to the sediment samples following the U.S. EPA Method 3050B: Acid Digestion of Sediments, Sludges, and Soil [16].



Preparation of Calibration Curve. Pb solutions with concentrations of standard true values 0.05, 0.10, 0.30, 0.50, and 1.0 ppm were prepared following the standard addition method. The standard curve was created using the absorbance values measured for the working standards. It showed the relationship between the absorption of monochromatic light in the spectrophotometer and the known Pb concentration.

FAAS Analysis. The Pb concentrations in the sediment samples were then analyzed using the Shimadzu AAS AA-7000F model with Lamp ID: Pb-1, wavelength of 283.3nm, slit width of 0.7nm, lamp Mode: BGC- D2, and low peak at 10mA. It uses an acetylene gas flow rate of 2.0 L/min and a support gas flow rate (compressed gas) of 15l/min. For each sample, the instrument performed two replicate analyses. The average of these replicates was subsequently calculated and utilized in assessing the sediment quality by established SQGs.

Data Analysis. The concentrations in ppm of analyte Pb in the sample were compared with the permissible concentrations set by the U.S. EPA Toxicity Classifications and the NOAA Screening Quick Reference Table for Inorganics in Marine Sediment [11,12].

Safety Procedure. Possible harm from inhalation of fine sediment samples was mitigated by wearing safety gear such as safety goggles, face masks, and gloves. Handling of strong acids with fumes was done in a fume hood. The experiment was conducted with the guidance of a laboratory supervisor.

Results and Discussion. - The yielded actual concentrations slightly deviated from the standard target values of the calibration curve due to an inaccuracy during the preparation of the standard solutions.

Table 1. Target standard concentration, generated actual concentration, and absorbance values of lead as yielded from the FAAS

Target Standard Concentration (ppm)	Actual Concentration (ppm)	Absorbance
0.05	0.0247	0.0265
0.10	0.1105	0.0282
0.30	0.3325	0.0326
0.50	0.4839	0.0356
1.00	0.9986	0.0458

Nonetheless, a straight line was approximated through the data points using linear regression, and its equation was best described as $y = 0.0198x + 0.0260$. The line has a slope of 0.0198 and an r^2 value of 0.9983 from a linear fit.

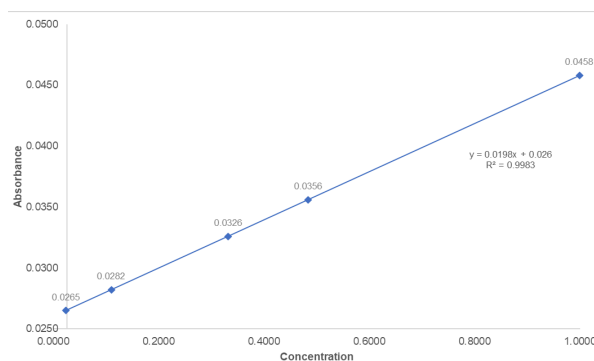


Figure 3. Standard Curve for Lead Concentration Analysis

The Pb concentrations were calculated by substituting their measured absorbance values into the equation of the standard curve. The instrument-run replicates of unknown concentrations of Pb are shown in Table 2.

Table 2. FAAS yielded concentration and absorbance of lead from samples with two instrument runs each.

Sediment Sample	Absorbance	Concentration (ppm)
1	0.0307	23.66
	0.0307	23.66
2	0.0289	14.58
	0.0292	16.09
3	0.0283	11.55
	0.0286	13.06
4	0.0281	10.54
	0.0286	13.06

The statistical analysis of the Pb concentrations, including the mean and standard deviation is presented in Table 3. These values were calculated using the results from the two instrument-run readings of each of the four samples.

Table 3. Mean and standard deviation of the two instrument-run readings of each sample.

Sediment Sample	Mean (ppm)	SD (ppm)
1	23.66	0.00
2	15.34	1.07
3	12.31	1.07
4	11.80	1.78

The average lead concentrations in the samples were assessed with the SQGs: U.S. EPA and NOAA Screening Quick Reference Table for Inorganics in Marine Sediment. For samples 1, 2, 3, and 4, the values are 23.66, 15.34, 12.31, and 11.80 ppm, respectively. The U.S. EPA provides three classifications for Pb concentration ranges: non-polluted, moderately polluted, and heavily polluted with values of less than 40, 40 to 60, and greater than 60 ppm. NOAA's SQGs for lead in



marine sediment provided values of 30.24, 46.70, 112.0, and 218.0 ppm for Threshold Effect Limit (TEL), Effects Range Low (ERL), Probable Effect Limit (PEL), and Effects Range Median (ERM).

Table 4. NOAA and US.EPA Classification of Heavy Metal Concentrations in MacArthur's Wharf

Heavy Metal	NOAA (ppm)				EPA (ppm)		
	TEL	ERL	PEL	ERM	Non-Polluted	Moderately Polluted	Heavily Polluted
Pb	30.24	46.70	112.0	218.0	<40	40-60	>60

The lead concentrations in the docking area of MacArthur's Wharf were found to decrease with increasing distance from the innermost section. Sediment sample 1, located at 0 m from the innermost portion of the docking area, exhibited the highest concentration of lead with a value of 23.66 ppm. Such results concurred with the study of Qian et al. (2015) [17] as it was observed that high concentrations of toxic metals are commonly found in sediments near industrialized coastal areas. Pb in the sampling areas may be particularly attributed to domestic waste and run-off from surrounding residential areas, fishing boats and vessels, and passenger boats plying and stationed in the area [18]. Furthermore, studies have found that HM levels were significantly higher during the dry season in both water and sediment samples due to decreased water activity resulting in sediment accumulation [19]. In contrast, sample 4 showed the lowest amount since it was located further away from commercial and residential areas. However, the researchers were unable to collect sediment samples from other sampling sites, such as in commercial areas where frequent shipping activities occur.

The observed lead concentrations from all four samples were well within the permissible levels and complied with the standards set by the U.S. EPA and NOAA. According to the U.S. EPA toxicity classification, all sediment samples were found to be non-polluted as their concentrations were determined to be less than the set value of 40 ppm. For the NOAA Screening Quick Reference Table for Inorganics in Marine Sediment, the TEL, with a permissible level of lead at 30.24 ppm, is the level of sediment contamination at which benthic organisms begin to exhibit toxic responses. The PEL is the concentration at which the majority of benthic organisms exhibit toxic responses and has a permissible concentration of 46.70 ppm. Harmful effects on the surrounding environment are rarely observed at concentrations below the ERL value of 112.0 ppm, while concentrations above the ERM value of 218.0 ppm frequently result in harmful effects. Concentrations between ERL and ERM are those in which harmful effects would occasionally occur. The determined concentrations of all four samples were below both the TEL and ERL, indicating that benthic organisms in the area have not exhibited toxic responses, and harmful effects are rarely observed.

Pb in the sampling areas may be attributed to several sources, including domestic waste and run-off from surrounding residential areas, fishing boats and vessels, and passenger boats plying and stationed in the area. Sediments serve as an adsorptive sink wherein heavy metals and other particles accumulate as they get quickly removed from the water body [20, 21]. The Second State of the Coasts of Guimaras 2018 has reported total and fecal coliforms that exceeded the standard provided by the DENR for Class SC bodies of water [22]. Though their presence and contamination may suggest exceeding levels of Pb, detected Pb concentrations were well within the permissible levels. The State of the Coasts report also monitored the physicochemical properties of water, such as pH, temperature, and dissolved oxygen. It supported the current study's findings that the water quality standards were satisfied, and it suggested that heavy metals not be contaminated.

Few studies have addressed heavy metal pollution assessments in sediments in the Philippines. Although heavy metals are naturally occurring elements, anthropogenic activities such as mining and smelting operations, industrial production and usage, home and agricultural use of metals, and transportation are the main causes of environmental contamination and human exposure [10]. Bacteria can be used as heavy metal concentration bioindicators and thus as indicators of water and sediment quality [23]. The observed lead concentrations that are within permissible levels may oppose the monitored exceeding coliform levels that would otherwise suggest also exceeding levels of heavy metal concentrations. However, these low concentrations of heavy metal may be attributed to the nearby mangrove forestation.

One factor that may have affected the low presence of lead in the area is the nearby mangrove forestation which is approximately 30 m to 70 m away from the docking area. Studies have found that the roots of certain mangrove species have a high potential for absorbing heavy metals and could serve as a natural phytoremediation treatment [24]. However, current monitoring of the mangrove forestation of the area and its physicochemical properties was not taken into account, thus their relationship with the observed lead concentrations cannot be determined for certain.

Domestic waste and run-off due to industrial activities contributed to the high lead concentration in the innermost section of the docking area of the sample site. The low lead concentration of some parts may be attributed to the nearby mangrove forestation where the study of Nazli and Hashim (2010) [24] found that the roots of some mangrove species have a high potential for absorbing heavy metals and could have served as a natural phytoremediation treatment. In addition, the found lead concentrations that are within permissible levels may oppose the monitored exceeding coliform levels that would otherwise suggest also exceeding levels of heavy metal concentrations. All four samples were able to fulfill the permissible lead concentration set



by the U.S. EPA and NOAA, implying that the sampling location, MacArthur's Wharf docking area, is not polluted with lead, benthic organisms in the area have not exhibited toxic responses, and harmful effects are rarely observed.

Limitations. Due to the rapid return of high tide upon arrival at the docking area, the researchers were unable to collect the intended three replicates per sample area distance (right side, left side, center), and only managed to collect samples from the center section of the docking area. Second, statistical analysis tools were not utilized for the assessment of the detected concentrations of Pb for any significant differences if it is within the permissible levels.

Conclusion. - The results obtained from the FAAS analysis showed that all four samples were able to fulfill the permissible lead concentration set by NOAA (at <30.24 ppm) and the U.S. EPA (at <40 ppm). Sediment sample 1 contained the highest lead concentration of 23.66 ppm. Samples 2 through 4 had concentrations of 15.34 ± 1.07 ppm, 12.31 ± 1.07 ppm, and 11.80 ± 1.07 ppm, respectively. The findings imply that MacArthur's Wharf, Guimaras, is not polluted with lead.

Recommendations. - The researchers recommend identifying a schedule for lower tides to have more time to collect samples from the docking area (right side, left side, center). It is also recommended that the researchers utilize statistical tools such as independent samples t-test for their assessment of the detected concentrations of Pb for any significant differences if it is within the permissible levels.

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Physicochemical properties of *Artocarpus heterophyllus* peels packaging paper coated with fish gelatin-palm wax-lemongrass oil

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Article Info	Abstract
<p>Submitted: June 29, 2023 Approved: January 17, 2024 Published: February 25, 2024</p> <p>Keywords: jackfruit paper coating FTIR spectroscopy water absorption tear resistance</p>	<p>Paper demand in the Philippines is increasing by 2.5% each year since 2016, including packaging paper. To address this demand, paper made from <i>Artocarpus heterophyllus</i> peels (AHP) has been used for packaging but it had low water barrier properties. A coating composed of fish gelatin, palm wax, and lemongrass essential oil (GPL) increases the physical, mechanical, and functional properties of paper. This study aims to determine the physicochemical properties of packaging paper made out of AHP coated with GPL. This includes water absorption, tensile strength, and chemical composition. Results showed that the water resistance of AHP-GPL was weaker than other packaging papers. The tear index was lower than kraft but possessed similar values with other non-wood papers. Attenuated total reflectance - Fourier Transform Infrared Spectroscopy (FTIR) results revealed that the peaks closely correspond to cellulose, which is a primary component of paper. This study concludes that AHP-GPL does not comply with paper packaging standards in water absorption and tear index.</p>

Introduction. - The total annual demand for paper in the Philippines has increased by 2.5% every year since 2016, with the packaging paper industry experiencing a high growth rate [1]. Packaging paper possesses low moisture resistance due to its composition, allowing moisture to pass through and contaminate the contents [2] easily. To combat this weakness, coatings are added to increase their water barrier and mechanical properties [2].

Artocarpus heterophyllus (AH), commonly known as jackfruit, holds significant importance as a valuable crop in the Philippines [3, 4]. AH peels are often discarded as solid waste. According to the Philippine Statistics Authority [5], an average of 2,406 metric tons of AH waste was produced from 2019 to 2021 per year. The biodegradation of AH peels through anaerobic digestion produces air pollutants such as methane and carbon dioxide [6].

Lothfy et al. [9] tackles the use of *Artocarpus integer* peels as paper, and are compared to the standards of commercial paper. Results present that it has good mechanical properties but possesses low wet tensile strength, strain, and tensile energy absorption characteristics comparable to wood-based paper. It does not tackle other parameters such as biodegradability and water absorption. The use of *Artocarpus heterophyllus* paper (AHP) in packaging could be increased by enhancing its current features by addressing the weakness revealed in prior studies and boosting water resistance and other characteristics. Syahida et al. [7] conducted a study on the effects of kraft paper coated with an

FG-PW-LEO (GPL) coating. The coating was made out of fish gelatin (FG), palm wax (PW), and lemongrass essential oil (LEO). FG has great potential for application as a paper coating due to its biodegradability and good film-forming properties [8]. PW is preferable due to its low cost, high availability, nontoxicity, excellent hydrophobicity, and biodegradability [7]. The lemongrass essential oil will act as the antioxidant property of the coating. The results prove that GPL coating can improve the water barrier, biodegradability, and mechanical properties of paper.

The validity of materials is often confirmed through Attenuated total reflectance - Fourier transform infrared spectroscopy (ATR-FTIR). Studies [10] use ATR-FTIR spectroscopy to characterize and identify functional groups found not only in paper [11,12] but also in its components such as cellulose and lignin [13,14].

Based on the standards of the Technical Association of the Pulp and Paper Industry (TAPPI) 441, water absorption is evaluated by measuring the weight of water absorbed in a period of time using a Cobb tester. Syahida et al. [7] tested the water absorption of kraft paper with GPL coating. The coated kraft paper had lower water absorption values which indicates better water resistance [7].

Meanwhile, tear resistance evaluates the strength of a paper [15]. The study of Lothfy et al. [9] measured the tear index of *Artocarpus integer* paper. The value of the tear index they obtained was lower



than the commercial paper they compared. The tear index can be obtained by dividing the tearing resistance by the grammage of the paper [15].

Exploring the capabilities of AHP with different coatings and studying more parameters can help determine the most effective coating that can amplify the properties of the AHP. The study's outcome can provide additional information about more ways to reuse AH wastes rather than letting AH cause pollution. In addition, this can determine if AHP-GPL can help address the rise of paper demand. It can also encourage and further the development of AHP as an alternative packaging material. Moreover, this can help the environment by turning *Artocarpus heterophyllus* peels into paper rather than letting them biodegrade and cause pollution

This study aims to determine the physical and mechanical properties of packaging paper made out of *Artocarpus heterophyllus* peels (AHP) coated with Fish Gelatin-Palm Wax-Lemongrass Oil (GPL) and to be compared with the respective kraft paper standards. Testing the AHP coated with GPL coating (AHP-GPL) will help evaluate if the GPL coating can address the low barrier water properties of the AHP paper and determine if it can be on-par or even better than the given standard for papers.

Specifically, the aims of this study are to:

- (i) identify functional groups found within the AHP produced via Attenuated Total Reflectance Fourier-Transform Infrared (ATR FTIR) spectroscopy, and ensure the validity via comparison to literature;
- (ii) measure the water absorption (WA) of GPL-coated AHP (AHP-GPL) via the Cobb Test, and compare to corresponding standards; and
- (iii) determine the tear resistance (TR) of AHP-GPL by using a tear tester, and calculate the TI for comparison to existing literature.

Methods. - Papermaking followed a modified soda pulping process to extract pulp from *Artocarpus heterophyllus* peels [9]. The mold and deckle used are 27 cm by 22.5 cm in length and width, allowing each sheet of paper to form one sample for the Cobb test. The preparation of the coating was made in the same process as in Syahida et al. [7] which consists of FG, PW, and LEO as its key ingredients. GPL coating will then be applied to the created paper samples.

In total, 10 sheets of AHP-GPL were created. Five samples were used for the Cobb test, each measuring 12.7 by 12.7 centimeters in length following the recommended dimensions of the sample by Central Philippine University (CPU) - Packaging Engineering Laboratory. For the tear resistance (TR), five sheets of paper were delivered to the CPU - Packaging Engineering Laboratory for testing.

Preparation of the AHP-GPL. Creating the GPL-coated *Artocarpus heterophyllus* Peel Paper to be used for sample testing involved four steps: formation of paper from AH peels, verification of the AHP, creation of the coating, and the application of GPL coating to the AHP. Paper creation was based on Lothfy et al. [9] with modifications to produce ten sheets of 27 by 22.5 cm AHP. The process began with AH peel drying where the researchers used the laboratory oven from the Philippine Science High School - Western Visayas Campus (PSHS-WVC) heating room, the peels were dried for four hours, at 70° Celsius. The resulting dried peels underwent the soda pulping process, by boiling the peels with 16% (w/w) NaOH for 1 - 2 hours. The resulting pulp was cleaned and dried, then placed in the mold and deckle to form a sheet of paper. The paper in the mold dried after 24 hours. The GPL coating and application were similar to Syahida et al's [7] where a coating made from FG, PW, and LEO is applied to the paper samples.

FTIR Spectroscopy. FTIR Spectroscopy was performed using the Shimadzu IRAffinity-1S at the PSHS Chemistry Instrument Room. The Attenuated Total Reflectance (ATR) accessory of the Shimadzu IRAffinity-1S was used to enhance the surface sensitivity of the machine, leading to more accurate results. Ten scans were performed to ensure the accuracy of the spectra and were set to absorbance, where the peaks were shown going upwards. The range of the scanned spectra was from 700 to 4000 cm^{-1} . The paper composition was confirmed by comparing the spectra to existing literature. [10,13,16].

Water absorption. Five samples of AHP-GPL measuring 12.7 by 12.7 centimeters in length, as recommended by the CPU's Packaging Engineering Laboratory, were used for the measuring of WA. The resulting data were expressed in the standard Cobb Value units: g/m^2 .

$$\text{Cobb Value} = (W_f - W_i) \times 100$$

W_i is the initial weight of the paper after the pouring of water and W_f is the final weight of the paper before the pouring of water.

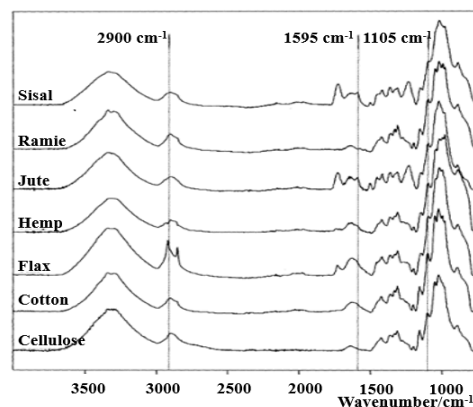


Figure 1. FTIR spectra of cellulose fibers from [10]



Tear Resistance. After submission to CPU's Packaging Engineering Laboratory, three sheets of the sample material with dimensions of 7.62 by 6.35 centimeters were torn together through a fixed distance using the pendulum of an Elmendorf-type tearing tester in the cross direction, following the standard of ASTM D689. The process was repeated once again in the machine direction. The work done in tearing was measured by the loss of potential energy of the pendulum. The resulting data was measured in grams-force indicating tearing strength (*gf*). Tear index was then calculated by dividing the average tear resistance of the sample by its grammage.

$$\text{tear index} = \frac{\text{average tearing force (gf)} \times 9.81}{\text{average grammage (g/m}^2\text{)}}$$

Data Analysis. The WA of AHP-GPL was submitted to laboratories for testing and as such, required no further calculations before data analysis. The data was compared to related literature to assess the quality of the two parameters.

Safety Procedure. To ensure safety from possible hazards, proper laboratory procedures were observed by the researchers. Proper laboratory equipment and protective clothing were worn during the handling of chemicals such as NaOH. During the data-gathering process, the Science Research Assistant (SRA) of PSHS-WVC and the research adviser supervised the researchers to ensure their safety.

The proper disposal of the excess materials after the conduct of the data-gathering process was observed. The NaOH used during the soda pulping process was stored in a plastic container as advised by the SRA and was then stored in the Chemistry Laboratory. To avoid clogging the drains of the laboratory, the researchers wait for the palm wax to solidify before scraping and disposal through the garbage gin.

Results and Discussion. - FTIR Spectroscopy. The AHP spectra matched the functional groups of cellulose, hemicellulose, and lignin, which are key components of paper. Hydroxyl and methyl bands were found in the single bond area while several tiny sharp peaks were found in the double and triple bond areas. In the fingerprint area, overlapping peaks are widespread and include large ranges and small sharp peaks, most of which are related to the components of the paper. The most significant functional groups of the paper are -OH, -CH, C=O, and C-O. Majority of the peaks in the spectra correspond to cellulose (3036 to 3639, 2800 to 3000, 1779 to 1596, 1173 to 840), while the sharp peaks in the single and triple bond region are attributed to lignin's functional groups. The most significant functional groups for paper, according to Munajad et al. [12], are -OH (3700 to 3000 cm^{-1}), -CH (3000 to 2700 cm^{-1}), C=O (1700 cm^{-1}), and C-O (1500 to 900 cm^{-1}). These functional groups coincide with those of cellulose, hemicellulose, and lignin, which are the main components in paper [11,14]. Furthermore,

paper contains more cellulose than lignin due to the removal of lignin and other additives during the papermaking process [11] with short, sharp peaks caused by the functional groups of lignin (1499 to 1596; 2397 to 2192; and 2134 to 1870 cm^{-1}) [16, 17].

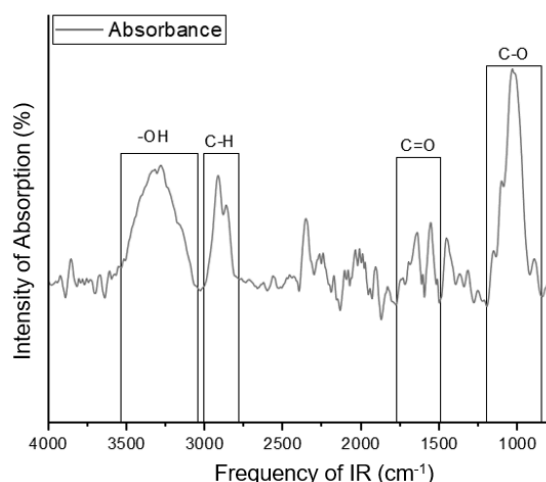


Figure 2. FTIR Spectra of uncoated AHP with the functional groups of paper indicated.

Water Absorption. Laboratory results by CPU - Packaging Engineering Laboratory showed that the Cobb Test of the first three samples had an average water weight of 135 g/m^2 . Meanwhile, two of the five submitted samples failed during testing due to leakage. Two of the submitted samples that failed due to leaking may be caused by multiple factors. Lack of equipment in papermaking can lead to an inconsistent thickness around the paper as mechanical papermaking equipment provides a more even pulp distribution [18]. In addition, microscopic holes can occur during the papermaking process, as they cannot be seen by the naked eye.

The water resistance of AHP-GPL is lower than kraft paper, which possesses a water weight of $40 \pm 5 \text{ g/m}^2$. A lower water weight value means it has a better water resistance property [7].

Table 1. Cobb test results of AHP-GPL.

Specimen	Weight of water in g/m^2 (Cobb Value)
Sample 1	103
Sample 2	141
Sample 3	161
Sample 4	(Failed)
Sample 5	(Failed)
Std. Deviation	29.5
Average	135 ± 5



Tear Resistance. The average force required to tear the three samples of AHP-GPL is 87.105 gf. This is converted to millinewtons and divided by the grammage such that the tear index of AHP-GPL is calculated to be 6.117 mN.m²/g.

Table 2. Tear test results of AHP-GPL

Sample	Tearing Force (g)	
	Cross Direction	Machine Direction
1	80.00	80.00
2	96.00	101.3
3	101.3	64.00
Std. Dev.	11.10	18.73
Average	92.44	81.77

This is higher than AHP with no coating, which has a tear index of 0.16698 mN.m²/g, which might indicate GPL coating's tear resistance-improving properties [9]. However, the increase was not enough to be comparable to kraft paper. Kraft paper is often used for high-tensile packaging applications and has a minimum tear index of 8-10 mN.m²/g [19, 20, 21]. A factor that can be taken into account is the difference in grammage between the AHP-GPL and kraft paper. The grammage of kraft paper is 70 g/m² [20], while the calculated grammage of AHP-GPL is 139 g/m². The tear index is also similar among other non-wood fiber papers such as kaun straw, chia, and mustard stalks, which have a tear index of 6.23 mN.m²/g, 5.9 mN.m²/g, 5.9 mN.m²/g respectively [22]. The AHP-GPL has lower mechanical strength than paper made from unbleached kraft pulp, possibly due to the soda pulping process [23]. Although, the TI of AHP-GPL is comparable to other chemical pulps such as softwood sulphite, hardwood sulphite, and hardwood sulphate pulps [15].

Limitations. The tensile strength test cannot be performed due to the lack of an available Universal Testing Machine (UTM). Therefore, tear resistance was the alternative parameter that the researchers tested. Handmade papermaking methods were also utilized, causing inconsistencies in the texture and thickness of the paper created. Furthermore, the unavailability of libraries meant that the assignment of peaks was limited, leading to the reliance on pre-existing literature for FTIR spectroscopy data analysis. Due to the distance of FPRDI, the researchers are unable to conduct the testing of tensile strength in person.

Conclusion. - AHP-GPL packaging paper did not meet the physicochemical standards of other packaging materials and non-wood fiber papers. ATR FTIR spectroscopy showed that AHP contains functional groups present in cellulose, hemicellulose, and lignin, which are major components of paper. However, AHP-GPL had a water absorption Cobb value of 135 g/m², which is inferior to other

packaging papers. AHP-GPL's tear index was 6.117 mN.m²/g, lower than kraft paper but higher than AHP without GPL coating, on par with other non-wood fiber papers like kaun straw, chia, and mustard stalks.

Recommendation. - The results of this study may be improved by using a papermaking method that reduces the chance of micro punctures from occurring. The use of equipment dedicated to papermaking can improve the quality of the created *Artocarpus heterophyllus* peel paper, having a more consistent texture and thickness in each area. This can also avoid unnecessary creases and unevenness in the paper. Additional methods during the papermaking process such as pulp beating or adding additives in the pulp can also benefit the properties of the samples. Exploration of different bio-based coatings can also help test the properties of AHP. The tensile strength of the AHP-GPL should also be investigated to obtain a more comprehensive understanding of the mechanical strength of the paper. Additionally, FTIR spectroscopy should also be performed on the coated AHP. Other parameters for packaging paper such as porosity, oil resistance, and burst index should also be tested.

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Determining Forest Cover Change In National Greening Program Sites In A High Conservation Priority Area By Utilizing Remote Sensing Techniques

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Article Info	Abstract
<p>Submitted: Jun. 27, 2023 Approved: Jan. 24, 2024 Published: Apr. 5, 2024</p> <hr/> <p>Keywords: QGIS NGP remote sensing forest cover reforestation</p>	<p>Deforestation in the Philippines resulted in a reduction in forest cover to just 10% of its original size in recent decades. To address deforestation, the Philippine government introduced the National Greening Program (NGP) and the Enhanced National Greening Program (ENGP). However, earlier studies have found that previous evaluations of these initiatives failed to sufficiently assess their impact on forest cover in the respective implementation areas. Thus, this study utilized Remote Sensing techniques to evaluate the effects of these programs in Brgy. Minoyan, Murcia, Negros Occidental (123.1199°E, 10.4983938°N), which is the largest NGP/ENGP planting site in Western Visayas, a region categorized as "highest conservation priority". The implementation of ENGP increased forest cover by 223.9 hectares and a decrease in grasslands and barren land by 192.2 ha and 31.8 ha, respectively. These findings indicate an increase in forest areas highlighting the program's effectiveness.</p>

Introduction. - Deforestation has been a pressing issue present in the Philippines [1]. Its prevalence is evidenced by the fact that the country's forest cover has significantly decreased in past decades, as the forest cover in the country now only represents 10% of its original size [2]. This decrease in forest cover due to deforestation may cause a multitude of negative impacts on the environment such as biodiversity loss, exacerbation of climate change, depletion of water and food resources, and an increase in poverty [3].

In line with these issues, the government launched the National Greening Program (NGP) in 2011 under Executive Order 26 series of 2011. This program involved planting seedlings across the country from the year 2011 up to 2016. The underlying state policy of this initiative is to achieve sustainable development in the forestry sector by addressing poverty reduction, food security, biodiversity conservation, and climate change adaptation and mitigation. This was later followed by the Enhanced National Greening Program (ENGP) which aimed to expand upon the initiatives of the NGP throughout the years from the year 2016 up to 2028. These programs aim to bring back the vegetative cover of the country and to achieve impacts more than reforestation in line with the aforementioned underlying state policy. Moreover, the NGP and ENGP initiatives also align with Goal 15 of the United Nations Sustainable Development Goals, which aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land

degradation and halt biodiversity loss as it focuses on reforestation and sustainable forest management [4]. As the NGP and the ENGP aimed to bring reforestation to the Philippines, it is increasingly important to assess whether the activities have reached their desired impacts. In fact, Perez et al. [2] stressed the importance of the comprehensive monitoring of the forest cover changes associated with the program to improve assessment of the successes of these activities. Included in the sites for the implementation of the NGP was a bamboo plantation area in Brgy. Minoyan, Murcia, Negros Occidental, established in the year 2020 at the Bago River Watershed Reserve. The aforementioned NGP site is noteworthy as it is the largest in Western Visayas, wherein forest fragments are considered global centers of endemism and biodiversity [1]. This makes these forest fragments fall into the highest priority for conservation, according to the International Union for Conservation of Nature.

Considering the importance of monitoring the forest cover change associated with the greening programs, the researchers sought to determine the change in the forest cover throughout the implementation of these greening programs with the use of Remote Sensing (RS). This study is especially important as there have not been good ground confirmations of the reported successes in the areas of activities of the NGP and the ENGP [2]. The researchers utilized RS in determining the forest cover change, which is a technology and science used to observe, measure, and map objects on Earth's surface from a distance [5]. Although



Greening Program sites traditionally use Key Informant Interviews and Focus Group Discussions to determine the forest cover in a given area, the researchers utilized RS as it was recognized that remote sensing could be beneficial in measuring vegetation growth in those sites [6].

Given the benefits of RS and the importance of monitoring the ENGP, this study aims to:

- (i) Calculate the area of different land cover classes in the study site in 2020 and 2023 through the use of the Normalized Difference Vegetation Index and QGIS Tisler 3.24 and;
- (ii) Determine the percent change of the cover of different land cover classes in the study site throughout the implementation of the ENGP by using the percent change formula.

Methods. - The study is descriptive and it aims to evaluate and compare the change in forest cover in Brgy. Minoyan, Murcia, Negros Occidental, and measure the change brought upon by the ENGP on the forest cover in the area.

Study area. Negros Occidental (10.2477° N, 122.9888° E) is classified as a first-class province, and prioritizes the advancement of sustainable agricultural practices, while also emphasizing the safeguarding of its primary watersheds. The province encompasses 792,607 hectares of land. Out of this, 68% or 540,385.62 hectares are categorized as Alienable and Disposable Land, and the remaining 32% or 252,221.38 hectares are classified as Forestland [7]. Negros Island, as a whole, is one of the regions that encounter severe flooding, super typhoons, drought, biodiversity loss, and other natural disasters. These problems are further aggravated by the absence of integrated planning, coupled with insufficient capacity and dedication of local government units to include biodiversity conservation in local development and land use planning at the municipal, city, and provincial levels [8]. Furthermore, these problems also demonstrated the importance of strict implementation and monitoring of environmental activities conducted within the region. Upon consultation with the DENR, it was discovered that there are several NGP planting sites in Western Visayas, the largest among these is situated at Brgy. Minoyan, Murcia, Negros Occidental, a site established in the year 2020 in which bamboo species are the planted commodities. The planting site in the mentioned location is the chosen study site, as its massive area makes it ideal for RS as it allows for more training points. The study area included the implementation sites of the ENGP in Brgy. Minoyan, Murcia, Negros Occidental (123.1199°E, 10.4983938°N; 123.1895739°E, 10.5588658°N). The site used for the study was composed of a 547-ha reforestation site and a 100-ha reforestation site at the Bago River Watershed Reserve (Figure 1 & 2).

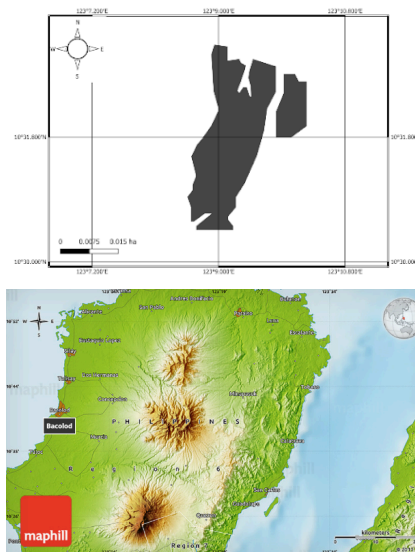


Figure 1. (top) Study area at Negros Occidental and (bottom) corresponding satellite image (MapPhl, 2011).

Satellite image collection. Using the Google Earth Engine, satellite imagery of the study site was obtained from Landsat 8. This also included the preprocessing of the images through a script in Google Earth Engine. This included cloud masking, temporal filtering, and mosaicking. The cloud coverage was set to 20% as was used by Dida et al. [9], and only the image with the lowest cloud cover satisfying the minimum threshold was considered.

Generation of Normalized Difference Vegetation Index. Using QGIS and the Semi-Automatic Classification(SCP) plugin. An NDVI image of the site was made through the use of the Band Calc function of the SCP plugin. For the raster calculation of the bands, the formula used for Landsat 8 is:

$$(NDVI)_{LandSat8} = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$$

Land Cover Classification. Through the Supervised Classification technique, the area was classified into different land cover classes. This included the setting of the Regions-of-Interest (RoIs) and processing the training points through the Spectral Angle Mapping (SAM) Algorithm.

Supervised classification included the setting of Regions-of-Interests (RoIs) through the use of the SCP plugin in QGIS [10]. The RoIs were classified into three predetermined classes, namely: Barren Land, Grasslands, and Forest as was adapted from Negassa et al. [11] and Adhikary et al. [12] as these were the observed classes in the study site.

Through the use of the SCP plugin in QGIS, each pixel of the study site was automatically classified through the SAM Algorithm in which each pixel was evaluated to the class it is most likely to be a member of [13].



Sieving. Through QGIS, the classified image was then processed through the Sieve tool. The sieve tool removed groups of 2 pixels or less from the image, this was done after visually assessing the impact of the number selection on the image [14] in order to reduce noise and achieve a better visual representation of the classification map [15].

Classification Report. A classification report of the classified image was generated through the SCP plugin in QGIS [16]. This report calculated the class statistics specifically: the area (in percentage) of each class in the study site classification map.

Data Analysis. An adapted version of the percent rate formula was used to analyze the raw data and determine the percentage of change for the program. The different percentage changes of each land classification's cover from 2020, the year that the study site was established, to its current state in 2023 was computed.

Safety Procedure. Potential safety hazards present in the study were the overuse of computers and improper posture while using computers. These hazards could have potentially given eyestrain and headaches, and musculoskeletal issues respectively. In order to combat this, proper safety procedures were exercised, such as following the 20-20-20 rule (a 20-second break every 20 minutes, to view an object 20 feet away) [17] and taking frequent short breaks from using computers. Furthermore, all data collected for this research was sourced from reliable and publicly accessible outlets. The data acquisition process was entirely conducted online, ensuring no harm to individuals or animals, and no parties were adversely affected during the course of this study.

Results and Discussion. - The study aimed to determine the change in forest cover through the implementation of the Enhanced National Greening Program (ENGP) in Negros Occidental, using remote sensing techniques. To determine this change, the area cover of different land cover classes in the study site in 2020 and 2023 was calculated through the use of the Normalized Difference Vegetation Index and QGIS software, and the percent change of the cover of different land cover classes in the study site throughout the implementation of the ENGP was determined using the percent change formula. These objectives were attained through Landsat satellite image collection using the Google Earth Engine; the generation of NDVI Images, land cover classification, generation of classification report using the SCP plugin in QGIS; sieving in QGIS; and the use of the percent change formula.

The land cover of each year was found using Landsat images using the Google Earth Engine, from where images of each year were then processed through the generation of NDVI Images, land cover classification, and sieving. The data was finally found using the generation of a classification report for each respective year. In the year 2020, barren lands comprised 113.0 hectares or 17.5% of

the entire plant site, while grasslands comprised 433.0 hectares or 66.9% of the entire plant site, and forests comprised 101.0 hectares or 15.6% of the entire plant site. Meanwhile, in 2023, barren land comprised 81.2 hectares or 12.6% of the entire plant site, while grasslands comprised 240.9 hectares or 37.2% of the entire plant site, and forests comprised 324.9 hectares or 50.2% of the entire plant site. This shows that in 2020, grasslands occupied the largest area in the plant site, followed by the barren land, while forests accounted for the smallest portion. By 2023, there was a shift, with forest cover increasing to occupy the largest portion, followed by grasslands, and then barren land accounted for the smallest portion.

Table 1. The area of the different land cover classes in 2020 and 2023 in hectares (ha).

	2020	2023
Forest	101.0	324.9
Grassland	433.0	240.9
Barren Land	113.0	81.2

Table 2. The area of the different land cover classes in 2020 and 2023 in percent (%).

	2020	2023
Forest	15.6	50.2
Grassland	66.9	37.2
Barren Land	17.5	12.6

The percent change in different land classes throughout the implementation of the ENGP in the study site was determined using the percent change formula. The formula was applied to the different classes, comparing their values between the start of the ENGP in the site in 2020 and its most recent state in 2023.

During the implementation of the Enhanced National Greening Program (ENGP) in the study site, it was found that there were negative percent changes in barren land and grassland of -28.1% and 44.4%, respectively, while the forest class showed a positive percent change of 221.8% (Table 3).

Table 3. Summary of percent change (%) from the establishment of the site in 2020 to the current state of the site in 2023.

	Forest	Grass-land	Barren Land
2020 to 2023	221.8	-44.4	-28.1



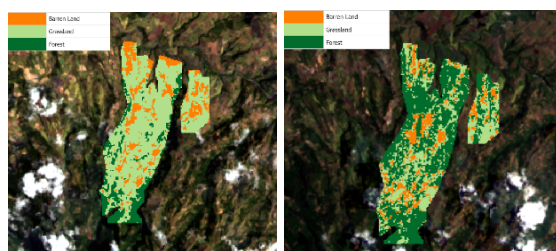


Figure 2. (left) Classified Study Site in 2020 and (right) Classified Study Site in 2023.

Through these results, it was observed, through the years of implementation of the ENGP in the study site that there was an increase in the percentage of the area that was covered by forest, demonstrating the positive effect the program had on the forestation site. The results of the study show that NDVI can be utilized in order to find the different land cover classes in the study site. This finding is in line with the study of Baloloy (2014), who found that NDVI has been a reliable indicator for spatiotemporal analysis of vegetation change. Given these results, it was found that through RS methods information about the land cover classification of the study site in the years 2020 and 2023 were obtained. This resultant information however was limited as only satellite images from Landsat were used which may lead to less accuracy.

The results of this study show that during the implementation of the greening programs, there was an increase in the growth of forests in the study site. The results of this study show that during the implementation of the ENGP in the study site forest cover increased while grasslands and barren land decreased. These changes show that the program has had a positive effect on forest cover in the study site. However, these results are contrasting with those of Perez et al. [2], wherein it was found that greening programs had no particular effect on forest cover in the greater Luzon area. These results may be contrasting due to underlying factors creating differences in the respective study sites, factors such as the availability of resources in the study site, specifically the availability of light, space, soil nutrients, and water; and physical conditions of the study site, specifically: elevation, topography, and climate conditions [19]. Moreover, the results of this study are limited as the researchers did not conduct the reclassification method in the SCP plugin and an accuracy assessment was not conducted.

Through the use of RS techniques, the change in forest cover in hectares throughout the implementation of the ENGP in Negros Occidental was determined. Moreover, NDVI was used to determine the change in forest distribution at the study site, supplementing the lack of studies on the implementation of the ENGP. In this study site, RS was successfully used to determine forest cover change in the area, showing that in future forestation measures, RS can be utilized to supplement data gathered from ground truthing.

Limitations. The resultant data from the research was solely utilized to determine the change brought about by the ENGP in the specific study site, rather than all unique and potential sites in the nation. In this study, the site utilized had only been established in the year 2020.

As a result, the research did not include the years that corresponded to the implementation of NGP (2010-2016) and part of the ENGP (2016-2019), as the study site was yet to be a part of both programs. Moreover, an accuracy assessment was not conducted due to the lack of necessary data. Finally, the study only focuses on the time span during which the ENGP was implemented in the study site and does not take into account any other anthropogenic or natural events in the area as its focus was the ENGP and its effects on the study site, and the study area used for the study was restricted to the given shapefile obtained from the Department of Environment and Natural Resources (DENR) Region VI, and only the bounds within this shapefile were considered the study site.

Conclusion. - From the year 2020 to 2023, the predominant class in the area changed from grassland in 2020 to forest cover in 2023. Moreover, in this span, barren land and grassland both decreased, while the forest cover in the study site increased. This shows that during the years of the implementation of ENGP, there was an expansion of forest cover in the area and that this was a result of the ENGP.

Recommendations. - For future research, the use of other satellite images may lead to increased accuracy compared to using only Landsat satellites. It is also recommended that future studies use datasets supplemented by images from other free satellites, such as Sentinel and MODIS. Furthermore, an accuracy assessment can be conducted to supplement their findings. Finally, utilizing the reclassification method in the SCP plugin is proposed to account for the redistribution of classes, thereby further supporting and substantiating the results of future studies.

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Trend analysis of drought indicators in terms of rice yield for drought identification in a Type III climate area in Central Philippines

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Article Info	Abstract
<p>Submitted: May 29, 2023 Approved: Jul 31, 2023 Published: Dec 31, 2023</p> <hr/> <p>Keywords: increasing temperature rice yield drought indices potential evapotranspiration precipitation</p>	<p>The most utilized drought indices are the Standard Precipitation Index (SPI) and the Standard Precipitation Evapotranspiration Index (SPEI), which are based on precipitation and temperature data. As tools that utilize a combination of meteorological data, this could provide a means to monitor and forecast drought conditions in relation with agriculture. Thus, this study aims to analyze the trend of SPI and SPEI for drought identification in terms of rice yield in Roxas City, Philippines, which is a Type III Climate area. Annual climate parameters (mean, minimum, and maximum temperature, precipitation, and potential evapotranspiration) were run through the Mann-Kendall test to determine trend significance, and rice yield was tested for correlation to SPI and SPEI. It was found that neither of the drought indices had a specific monotonic trend on a 12-month timescale. Rice yield had a weak negative correlation with SPI ($r = -0.050$) and a weak positive correlation with SPEI ($r = 0.065$), depicting the indices as weak agricultural indicators. However, other studies have found that this correlation is much stronger on a shorter timescale.</p>
<p>Introduction. - Rice was the most commonly consumed food item in the Philippines in 2021, with a roughly 110 million population having a 133 kg per capita rice consumption [1]. This is further supported by the increase in volume of the country's rice output, with 19.07 million metric tons produced in 2018 [2,3]. However, when compared with other Asian countries such as Vietnam, China, Thailand, Indonesia, and India, the Philippines had the second least annual yield [4].</p> <p>As an agricultural country, continuous monitoring of the current strategies' effectiveness is important. Information about the country's yield-climate relationship can provide a basis for projecting the impact of future climate change [2,5]. The threat climate change brings to the agricultural sector heightens with the foreseen increase in the frequency and severity of extreme weather events such as droughts and floods [6,7].</p> <p>Climate change and variability are leading factors that affect rice yield, with each 1°C temperature increase leading to a six percent decrease in total rice yield [8,9]. Moreover, water availability below the optimum requirement for the full expression of yield potential leads to drought stress [10].</p> <p>Ray et al. [11] investigated the relationship between rice yield and annual temperature extremes and found that temperature changes resulted in a -0.02 percent change in rice yield in the Philippines. However, Prabhakorn et al. [12]</p>	<p>stated that a shorter time step would better represent crop sensitivity to climate at each growth stage. Among the climatic variables, temperature and precipitation are the two fundamental variables commonly used as indicators for changes in climate [13]. In contrast, Vogel et al. [9] revealed that temperature-related indicators have a stronger predictive capacity for rice yield compared to precipitation-related indicators. The present study addresses this by using annual temperature extremes to investigate the effect of temperature on rice yield.</p> <p>Researchers often select precipitation-based indices because of their calculation convenience and standardization with respect to available data [14]. They also often base the selection of the drought index on its advantages in other regions. Pei et al. [15], however, suggest that different natural characteristics of different regions may contribute to the poor classification of drought. Furthermore, drought indices in general have a strong connection with agriculture.</p> <p>In the Philippines, PAGASA (Philippine Atmospheric, Geophysical, and Astronomical Services Administration) only uses the Standard Precipitation Index (SPI) to monitor drought events, which only takes precipitation into account. However, the Standardized Precipitation Evapotranspiration Index (SPEI), specifically, is more accurate than the SPI in terms of describing drought events because it takes temperature into consideration [12,16]. This study was formed to</p>



analyze the trend of two drought indices and correlate each index with the rice yield in a Type III Climate area, as identifying the variations between the drought indices and their characteristics was deemed to require further analysis by Pei et al. [15]. A Type III Climate area is defined by PAGASA [17] as one where the seasons are not very pronounced, with a short dry season lasting only from one to three months, either during the period from December to February or from March to May. It shares similarities with a Type I climate due to its short dry season; however, the season differences in Type I are more pronounced [17]. This study, therefore, has the potential to contribute valuable insights into the application of drought indices in Type III climate areas.

The Philippines' current water infrastructure has previously been identified as deficient in the National Climate Change Action Plan for 2011–2028 [18]. The findings of this study will improve understanding of the relationship between drought and rice yield, making it important to the country's agricultural research and climate change management plans. While current research and development focus on the creation of new technologies in agriculture, this study's focus is still in line with the recommended management practices for rice production in Asia [19].

The study aimed to determine the relationship between the drought indices SPI and SPEI and rice yield from 2005 to 2020. This is mainly due to the limitations of data availability for the rice yield data; the study was limited to 16 years only, from 2005 to 2020.

Specifically, the study aimed to analyze the trend of SPI and SPEI for drought identification in terms of rice yield in a Type III Climate area from 2005 to 2020 through the following objectives:

- (i) compute for the annual mean, minimum, and maximum temperatures of Roxas City from the daily data;
- (ii) compute for the annual precipitation of Roxas City from the daily data;
- (iii) compute for the annual Potential Evapotranspiration (PET) of Roxas City;
- (iv) compute for the annual Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) of Roxas City;
- (v) compare the graphs of the annual SPI and SPEI of Roxas City at the given timescale; and
- (vi) correlate the annual rice yield with the annual SPI and SPEI classifications of Roxas City.

Methods. - The methodology for this study was adapted from Prabnakorn et al. [12] and Pei et al. [15]. These studies provided the basis for conducting the Pearson Correlation and the Mann-Kendall tests,

respectively. Data was requested from identified government agencies (PAGASA and the Capiz Provincial Agriculture Office), and missing data were imputed using multiple imputation. SPI, SPEI, and statistical calculations from the meteorological data were conducted in the R environment version 4.1.2. Their yearly averages were taken using the total annual rice yield data. Pearson's correlation was then employed to identify whether linear relationships existed between the drought indices and rice yield.

Study Area. The study area of Roxas City, Capiz (11°36'00.72"N 122°44'58.74"E) was selected based on the completeness of the available climate and agricultural data. It is within a 25-kilometer radius from its weather station seen in Figure 1. Of the two PAGASA weather stations in Western Visayas, the Roxas City station had the more complete data. Additionally, the study area is a Type III climate area with its dry season that lasts from February to April [17].

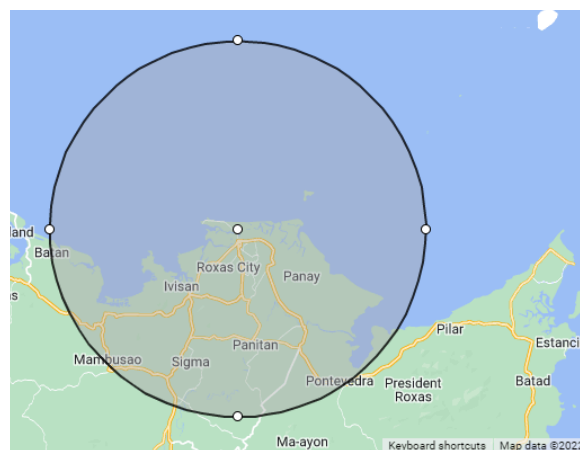


Figure 1. 25-km radial scope of the weather station's climate data

Tabulation and Imputation of Datasets. The raw data were tabulated in Google Sheets; however, there were missing values. In order to identify the data's missingness, the Little's Missing Completely At Random (MCAR) Test was used on the meteorological dataset. After identifying it as Missing Not At Random (MNAR), it was imputed with the random indicator method using the Multivariate Imputation by Chained Equations (MICE) algorithm.

Conduct of SPI and SPEI Analysis. The SPI expresses the amount of precipitation over time, while the SPEI calculates the difference between the cumulative precipitation and PET. The code for the SPI and SPEI analyses was adapted from Beguería and Vicente-Serrano [20]. PET was calculated using the Thornthwaite [21] equation, which is ideal when only temperature and precipitation data are available. Other equations, such as those of Hargreaves [22], also utilize temperature and precipitation; however, they returned a value of infinity when tested with the data, which was not considered significant.



$$PET = 1.6b\left(\frac{10T_m}{I}\right)^a$$

Where:

b is the total monthly daylight hours divided by 360

T_m is the monthly mean temperature

I is the annual heat index

a is the empirical constant; cubic function of I

Data Analysis. The resulting values from the SPI and SPEI calculations match a specific SPI and SPEI category that determines drought conditions in an area. This assessment for SPI and SPEI was adapted from Prabnakorn et al. [12] and the Standardized Precipitation Index User Guide of the World Meteorological Organization, respectively. The values from 2005 to 2020 were then graphed to analyze the variations.

Table 1. Dry and wet conditions corresponding to the seven SPI and SPEI categories.

Value	SPI Category	SPEI Category
≥ 2.00	Extremely wet (EW)	Extreme wet (EW)
1.50 to 1.99	Very wet (VW)	Severe wet (SW)
1.49 to 1.00	Moderately wet (MW)	Moderate wet (MW)
0.99 to -0.99	Near normal (NN)	Normal (N)
-1.00 to -1.49	Moderately dry (MD)	Moderate drought (MD)
-1.50 to -1.99	Severely dry (SD)	Severe drought (SD)
≤ -2.00	Extremely dry (ED)	Extremely drought (ED)

Conduct of the Mann-Kendall Test. To analyze the monotonic trend of the temperature, precipitation, PET, SPEI, and SPI data, the Mann-Kendall Test was conducted using the *MannKendall* function in R Software. The null hypothesis for this test is that no monotonic trend exists, while the alternative hypothesis is that a trend exists.

Conduct of Pearson Correlation. The SPI and SPEI values acquired from the SPI and SPEI analyses, along with the annual rice yield of the study area, were utilized to implement the Pearson Correlation Test using the *cor.test* function in R Software.

Results and Discussion. - The trend analysis done through Mann-Kendall showed that temperature and PET were both increasing, while precipitation showed no monotonic trend. A significance level of 95%, or a p-value of 0.05, was

presumed. The table below summarizes the results of the Mann-Kendall test.

Table 2. Outputs of the Mann-Kendall test with the climate data.

Dataset	Kendall's tau	2-sided p-value
Mean Temperature	0.205	2.5392e-05
Minimum Temperature	0.314	2.22e-16
Maximum Temperature	0.143	0.0032147
Precipitation	-0.00517	0.91591
PET	0.148	0.0023863
SPI	-0.00846	0.86266
SPEI	-0.0404	0.40647

Based on the values found in Table 2, the minimum temperature and mean temperature were the variables that exhibited the two most significant increasing trends. Their positive tau values indicated an increasing trend, with the strength of it increasing as it got closer to 1. Maximum temperature and PET also displayed a significant increasing trend. Precipitation was the only single climate variable that displayed no monotonic trend from 2005 to 2020. The SPI and SPEI values of Roxas City were also run through the Mann-Kendall Test in RStudio to assess whether a monotonic upward or downward trend exists in their generated graph of values. The results imply that no significant upward or downward trend exists among the annual SPI and SPEI values of Roxas City from 2005 to 2020.

SPI and SPEI Variations

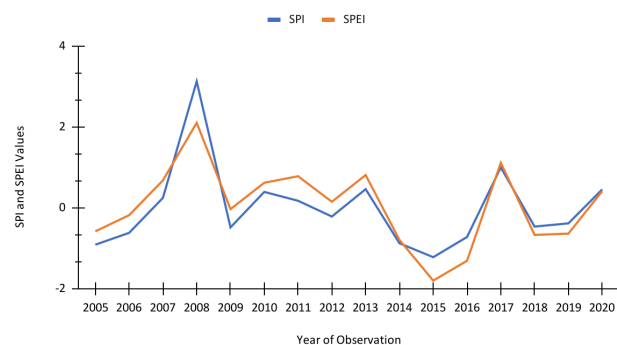


Figure 2. Combined graph of the annual SPI and SPEI values of Roxas City from 2005 to 2020.

The values of temperature and precipitation were compared with the climatological normals for Roxas City from 1991 to 2020 from Figures 3 to 6. The average values of mean, minimum, and maximum temperature from 2005 to 2020 all exceeded their respective climatological normals.



This indicates a warming trend within this timespan. Figure 7 shows the annual PET trend, while Figure 8 shows the annual time series of rice yield.

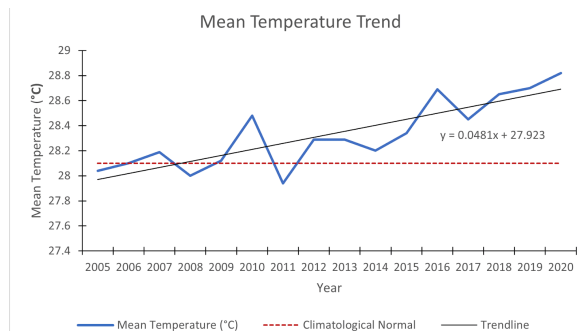


Figure 3. Graph of the annual mean temperature trend in Roxas City from 2005 to 2020.

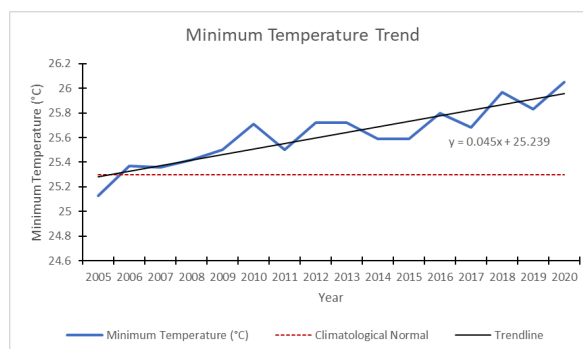


Figure 4. Graph of the annual minimum temperature trend in Roxas City from 2005 to 2020.

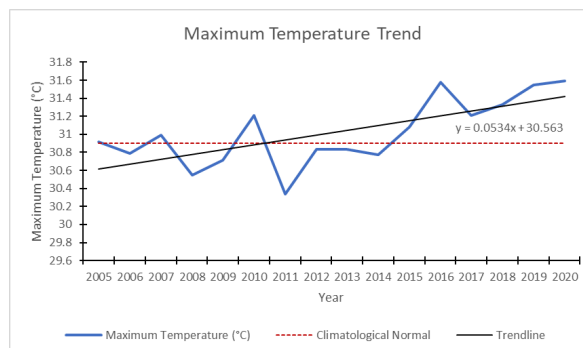


Figure 5. Graph of the annual maximum temperature trend in Roxas City from 2005 to 2020.

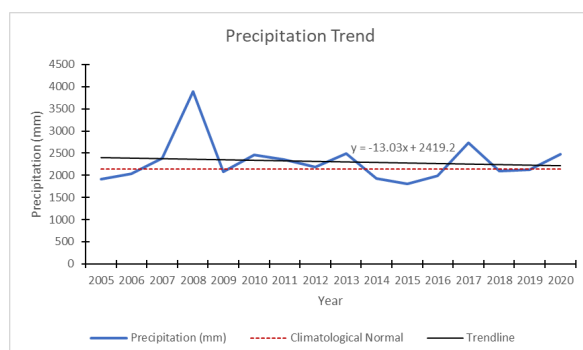


Figure 6. Graph of the annual precipitation trend in Roxas City from 2005 to 2020.

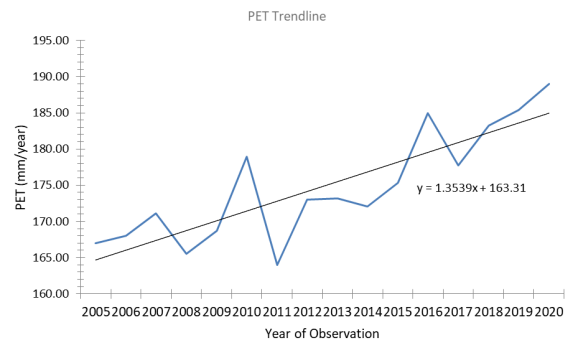


Figure 7. Graph of the annual potential evapotranspiration trend in Roxas City from 2005 to 2020.

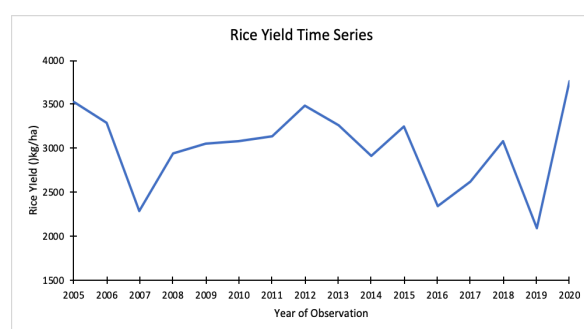


Figure 8. Graph of the annual rice yield trend in Roxas City from 2005 to 2020.

The Pearson correlation coefficient conducted between annual yield and SPI resulted in an r-value of -0.04972216 or -0.050, and the Pearson correlation coefficient between annual yield and SPEI is 0.06546188 or 0.065.

Pearson correlation coefficient values range from -1 to 1. If interpreted, Zvizdojevic and Vukotic [24] describe the major cut-offs as:

- 1 - a perfectly negative association between two variables
- 0 - no association between two variables
- 1 - a perfectly positive association between two variables



Furthermore, a positive Pearson correlation coefficient reflects that the two variables are directly proportional, while a negative Pearson correlation coefficient reflects that the two variables are inversely proportional. However, given the low correlation values, this would imply that the association between the drought indices and rice yield has no significant linear relationship or is nonlinear.

Some scientific evidence points towards temperature as the climate variable that holds significant influence over rice yield [25]. The results of the current study, however, show that despite the significantly warming mean, minimum, and maximum annual temperatures, rice yield trends still remain without a constant pattern. Interestingly, the study's precipitation trend was also neither significantly increasing or decreasing. As SPI and SPEI showed no significant upward or downward trend during the study period either, annual temperature and precipitation data alone may not be enough in characterizing rice yield trends.

Identifying and comprehending the risks that climate change poses to vulnerable sectors such as agriculture is critical for authorities to implement timely mitigation efforts. The weak correlations between rice yield and drought magnitudes for Roxas City suggest that drought magnitudes as measured by SPI and SPEI may not be a significant indicator of rice yield in some areas. Although the current impact is low, the influence on rice yield may be more serious in the future if temperatures continuously rise to a level that negatively targets specific growth stages of rice.

Limitations. In understanding the results of the correlation between the rice yield and the drought indices, factors such as irrigation and hybrid rice varieties were not considered in this study; the rice data utilized both rainfed and irrigated agricultural practices, which may have an effect on the rice yield data. These external factors that contribute to the growth stages of rice were not defined in this study, which looked at rice yield alone.

Conclusion. - The two drought indices have weak relationships with annual rice yield in Roxas City, Capiz. Annual SPI displayed a weak negative relationship, and annual SPEI displayed a weak positive relationship. Furthermore, both SPI and SPEI may not be strong predictors for rice yield.

Recommendations. - The applicability of SPI and SPEI may vary depending on the area's climate type [15], thus it would be ideal to look into other climate types as well. Other drought-sensitive crops may have higher linearity with the aforementioned drought indices. Conducting studies with the 30-year standard reference period would be more ideal to compare to climatological normals, and specifically for the rice yield data, it is recommended that the data be detrended in consideration of crop damage reports and other humanitarian influences in the analysis. Seasonal variations would be better observed on higher temporal resolutions (i.e. quarterly average) and may be given better analysis

through the implementation of an autocorrelation analysis. Lastly, future analyses may want to consider the type of relationship between drought indices and rice yield aside from the linear level.

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Determining the Impact of the COVID-19 Lockdown on Mangroves of a Class C Coastline in Iloilo City, Philippines through Remote Sensing

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Article Info	Abstract
<p>Submitted: Jun. 27, 2023 Approved: Oct. 22, 2023 Published: Dec. 31, 2023</p> <hr/> <p>Keywords: QGIS mangroves pandemic remote sensing COVID-19 lockdown</p>	<p>The growth of mangroves is negatively impacted by human activity; however, lockdowns were imposed across the Philippines during the COVID-19 outbreak, resulting in a decrease in human activity. This study determined the lockdown's impact in terms of the decrease in human activity on the mangroves in the Batiano River, Iloilo City, Philippines. The mangrove area was mapped yearly from 2017 to 2021 using the Quantum Geographic Information System (QGIS). Percent changes in the area every year were computed and showed results of 0.57%, -0.09%, 2.22%, and 1.08% in 2018 to 2021 respectively, compared to the immediate previous years. The marked increase from 2019 to 2020 can be attributed to mangrove cutting prohibition and preservation by the Department of Environment and Natural Resources (DENR). The percent change from 2020 to 2021 is higher compared to the years with no interventions and lockdowns, but cannot be attributed to the lockdown alone.</p>

Introduction. - Mangroves are types of trees that grow near bodies of water, such as rivers, seas, and other coastal areas. These types of trees are in decline due to anthropogenic factors which include conversion of the area to fish and shrimp ponds and urban development, which occupy the area of mangrove forests; logging (both legal and illegal), which reduces mangrove forests; and pollution [1,2]. The area that mangroves occupy in the Philippines has diminished from 500000 ha in 1918 to 120000 ha in 1994 because of natural and anthropogenic factors [3]. There have been multiple efforts to restore the mangrove forest cover in the country, done by the government and non-government organizations (NGOs), but until now, the mangrove forest cover has continued to be in danger [4]. However, in March 2020, lockdowns were implemented all over the country, which restricted going out unless necessary [5]. Land, water, and air pollution, which are some factors in the decline of mangroves, have decreased during the lockdown period, as shown in the studies by Aunan et al. and Diraviya et al. [6,7]. As it has been established that mangroves are also greatly affected by human activities and pollution, mangrove forests can be another metric by which the effect of the lockdown can be measured. In this study, the possible impact of the lockdown on the mangroves in the Batiano River, Iloilo City was determined by mapping using the Quantum Geographic Information System (QGIS) software [8]. The Batiano River is home to several marine species, with 16 of the 35 species of mangroves found in the Philippines, and is also significant for the fishing industry of the city, making the site significant for this study [9,10]. This study determined the impact of the lockdown on *Avicennia marina* mangroves in the Batiano River, Iloilo City in 2017, 2018, 2019, 2020, and 2021 by calculating the

area of mangroves each year and comparing the percent changes for every two years to analyze the trend in mangrove growth pre and post-lockdown.

With this, the study specifically aimed to:

- (i) determine the area of mangrove cover (10° 41' 31"N to 10° 41' 18"N and 122° 33' 00"E to 122° 33' 13"E) in the Batiano River, Iloilo City during 2017, 2018, 2019, 2020, and 2021 using QGIS;
- (ii) solve for the percent change in the area of mangrove cover yearly; and
- (iii) compare the percent changes of the aforementioned years.

Methods. - The methodology consisted of four major steps: gathering and georeferencing the satellite images of the chosen study site every year from 2017 to 2021 using Google Earth Pro and Smart GIS; mapping the mangroves by tracing them using polygons; calculating the mangrove area via the drawn polygons; and analyzing the data by comparing the percent changes during each year.

Study site. Iloilo City is a highly urbanized city in Western Visayas. The city is significant in providing function to the region for trade and commerce, education, research, and tourism. Furthermore, all of the barangays and districts comprising the city have also been classified as urban [10].

This study's chosen sampling site is located in the Batiano River, Iloilo City, Philippines (from 10° 41' 31"N to 10° 41' 18"N and from 122° 33' 00"E to 122° 33' 13"E). The Iloilo-Batiano River System falls under the



classification of Class C, which can be fishery water, recreational water for boating and fishing, or agriculture, irrigation, and livestock watering. This makes the river significant to the aquaculture, boating, and agriculture industries of Iloilo City [11]. The mangrove forest is also directly adjacent to a coastal community. Moreover, the rivers are home to 16 out of the 35 species of mangroves found in the Philippines, including one rare species [10]. The local government of Iloilo City declared through Executive Order 055 - Series of 2020 that the city would be put under enhanced community quarantine (ECQ) during 2020, making the chosen site suitable for assessment of the effects of the lockdown. The site's satellite image for the year 2021 is shown in Figure 1.

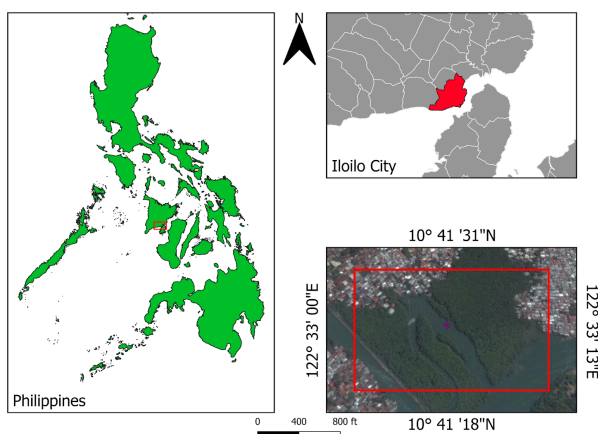


Figure 1. Study Site in the Batiano River, Iloilo City, Philippines.

The site was visited by researchers to determine the human activities, and mangrove tree planting and fishing were observed. The captain of the community was interviewed, and it was confirmed that the aforementioned activities were paused during the lockdown. The mangrove species used for tree planting in the area was confirmed to be *Avicennia marina*. Due to the area of mangroves being adjacent to a community, there was also a significant amount of trash found in the mangrove area and in the river. Shown in Figure 2 are the images taken during the inspection of the Batiano River and its mangroves.

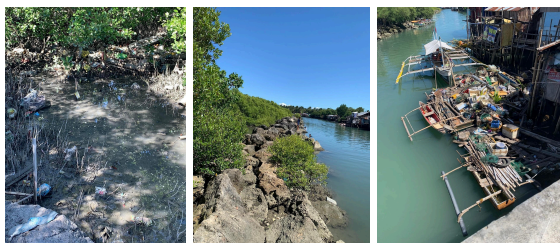


Figure 2. Mangrove area in the Batiano River.

Collection and Georeferencing of Satellite Images. One satellite image was collected each from April 27, 2017; February 9, 2018; March 2, 2019; April 18, 2020; and April 30, 2021. The images were obtained from Google Earth Pro version 7.3.2, an application that contains features such as being able to obtain a

satellite view of an area at different dates by changing the time. The satellite images needed for each date were then georeferenced in Smart GIS version 23.02.

Mapping of Mangrove Area. Before the mapping process, a site inspection was done to ensure that the plants being mapped are mangroves. The georeferenced satellite images' mangrove area was manually mapped in QGIS version 3.28.1 by tracing the area using a polygon and turned into a shapefile layer. If the mangrove areas were scattered, multiple polygons were created for each mangrove patch.

Calculation of Mangrove Area. After the tracing was completed, the attribute table of the shapefile layer was opened, and a new field was added, which served as the column for each polygon's area. The field calculator was then opened, and the command '\$area' was inputted, which automatically calculated the area size of each polygon. The given area sizes were then added to obtain the total area of the mangroves during the given year.

Data Analysis. The percent change in mangrove area cover was calculated. Next, the percent changes were then compared and the trend in the change of mangrove forest cover was observed. It was then analyzed whether or not the change in the mangrove area was affected by the lockdown. This is further explained in the discussion section.

Computing for the Percent Change in Mangrove Forest Cover. The percent change is the percentage of increase or decrease of mangroves in an area for the given year compared to the previous year. The percent changes were calculated using the formula:

$$\Delta\% = \frac{\text{Final Area} - \text{Initial Area}}{\text{Initial Area}} \times 100\%$$

The final area is the area of mangrove cover in a given year and the initial area is the area of the mangrove cover in the preceding year. A positive percentage indicated an increase in area while a negative percentage indicated a decrease.

Analyzing the Trend of Percent Changes. The percent changes that were calculated were used to assess the possible effects of the lockdown by analyzing the trend. The percent changes in the area both before and during the lockdown were compared.

Safety Procedure. This study mainly involved the use of digital data; therefore, the possible hazard that was foreseen was the radiation from the computers. This was mitigated by limiting the time spent facing computers, and while unnecessary, anti-radiation glasses were also reserved to be worn for protection in case problems arose when facing the computer during the data gathering procedure in the computer software. Furthermore, during the site inspections, there was a companion of legal age present in order to secure the site inspection process.



Results and Discussion. - The mangrove forest of the Batiano River, Iloilo City (from 10° 41' 31"N to 10° 41' 18"N and from 122° 33' 00"E to 122° 33' 13"E) was mapped from 2017 to 2021. Shown in Figure 3 are the mapped areas of the mangrove forest, where the change in the area throughout the years can be visualized with the initial year 2017 and the final year 2021.

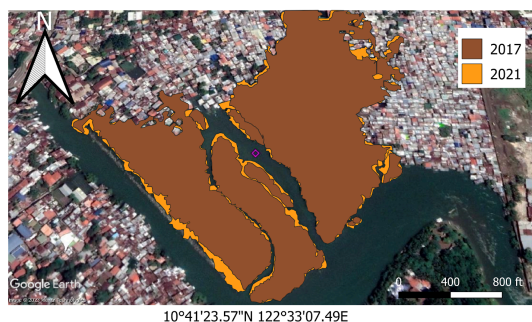


Figure 3. Change in mangrove forest cover, 2017 to 2021.

The areas calculated from the mangrove forest cover of the Batiano River, Iloilo City, Philippines, were 89283.79 m² (April 27, 2017), 89787.33 m² (February 9, 2018), 89707.32 m² (March 2, 2019), 91695.85 m² (April 18, 2020), and 92684.52 m² (April 30, 2021). Using the data gathered from the mangrove forest's area, the percent changes for every year were calculated. Percent changes in area were 0.57% from 2017 to 2018, -0.09% from 2018 to 2019, 2.22% from 2019 to 2020, and 1.08% from 2020 to 2021. A change of less than one percent was seen from 2017 to 2019, while an increase of more than one percent was seen from 2019 to 2021, with the highest increase from 2019 to 2020. Shown in Figure 4 is the trend of change in mangrove areas during the years 2017 to 2021.

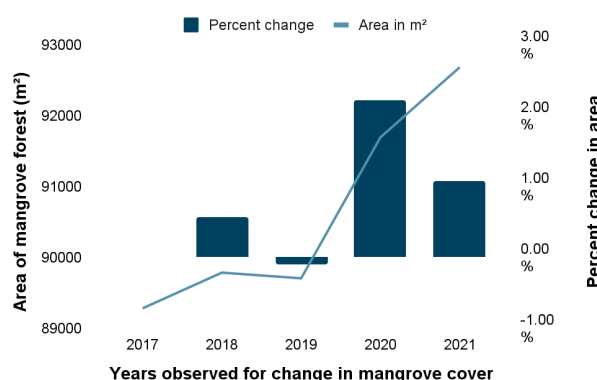


Figure 4. Area (in m²) and percent change of mangrove cover in the Batiano River, Iloilo City, Philippines, 2017 to 2021.

Mangrove area growth from 2017 to 2019 was gradual, despite other human activities present in the area potentially impacting the mangrove forest, due to the area's mangrove tree planting initiative that started in 2016. The gradual increase in the area can be attributed to the time mangroves take to grow, which is usually ten to twenty years until they fully mature [12]. Moreover, the *Avicennia marina* species

of mangrove grows in sandy, muddy, and coralline rock substrates [13]. The area's substrate is muddy, as observed from visiting the site, which is suitable for the species of *Avicennia marina*. This could have contributed to the area consistently increasing throughout the years except from 2018 to 2019. Common human activities that impact mangroves are those that require utilization of the forests' area, such as the expansion of aquaculture, tourism, and coastal development [2]. Moreover, mangroves are also used as resources, such as wood for construction and fuel [4]. However, this is not the case for the mangroves in the Batiano River, as the human activities found on the site do not involve the destruction of mangroves, like fishing and mangrove tree planting. Lastly, the decrease in area from 2018 to 2019 could likely be a personal error due to the methods being done manually.

An increase of 1988.53 m² or 2.22% occurred from 2019 to 2020. Additional information about the activities on the mangroves in the Batiano River, Iloilo City was gathered for possible explanations of the marked increase in area. There were mangrove tree planting activities that started in 2016 by the community's local government, and the prohibition of the cutting of mangroves in 2019 based on Republic Act No. 7161. There was also an intervention by the Department of Environment and Natural Resources (DENR) to preserve the mangroves in the area, which occurred from 2019 to 2020. When human activities are persistent, action toward the restoration of mangroves is needed to combat the impact of human activities.

There was a 1.08% or 988.67 m² increase in the area of mangroves from 2020 to 2021, which was during the lockdown. This can also be attributed to the intervention of the DENR and the adopted ordinance. However, the mangrove tree planting paused during the lockdown. This left the mangroves to just grow naturally, causing a slower increase in the mangrove forest's area. Nevertheless, there were no other human activities ongoing due to the lockdown. This might have contributed to faster growth than in 2017 to 2019. Additionally, studies have shown that improvements in environmental conditions were caused by the restriction of human activity due to the lockdown, shown in indicators of air quality and water quality [8,15]. However, the same cannot be concluded for mangroves, as there are other factors, such as mangrove tree planting, that may impact the mangrove forest differently, and changes in mangroves take longer to be noticeable [13].

The lockdown only had a partially positive impact on mangroves, as before the lockdown was imposed, other factors already had a positive impact. Improvements in environmental conditions during the COVID-19 lockdown did not take effect as quickly in mangroves as it did in pollution, due to reforestation efforts being present, which already helped the mangrove forest's conditions before the lockdown. With that, any increase or decrease in the area of mangrove cover in the Batiano River cannot be solely attributed to the lockdown.



Limitations. The limitations of this study mainly focus on its methodology. First, the availability of satellite images was limited, which specifically led to one of the images being low quality, making it prone to personal errors. Second, the mangrove forest cover was only monitored for the total area occupied, which could be different when it comes to its vegetation and colonization rate. Third, although the area was visited to ensure that the plants seen in the satellite images are indeed mangroves, it cannot be assumed for the whole area. Some parts of the forest are too far to be visited, which makes it difficult to determine whether there are other plants growing adjacent to the mangroves. Lastly, the years used for comparing the trend of growth before and during the lockdown only generalized the years in which the lockdown occurred, not the actual time frame of the lockdown.

Conclusion. - Generally, there was an increase in the mangrove area from 2017 to 2021, with a marked increase from 2019 to 2020. Although during the lockdown, there was an increase in area, it is not as high as the increase in the preceding year. Thus, the increase cannot be solely attributed to the lockdown, but prior human interventions such as mangrove tree planting, regulations to protect the mangroves, and government interventions were able to contribute to the increase in the area of mangrove forest cover.

Recommendations. - Satellite images from Google Earth Pro were used for mapping, but other satellite websites could be used for image collection so that the satellite images to be used are ensured to be available and high quality to avoid errors in future studies. Due to the limited available images, not all months had satellite images in Google Earth Pro version 7.3.2. Determining the conditions of a mangrove forest could be done by using other assessments, such as colonization rate, which indicates how quickly mangroves occupy a new area, and vegetation index, which determines the density and vegetation of plants in an area based on their color. Selecting an area without rehabilitations for mangroves can determine the impact of the lockdown better. Focusing on changes that occurred monthly instead of annually could be done in future studies to have a clear comparison of the change that occurred before and during the lockdown. Other parameters such as land pollution and grassland vegetation could also be compared. Lastly, no satellite images for the year 2022 were available on Google Earth Pro, which made this study unable to describe the status of mangrove forests after the lockdown; therefore, it is recommended that studies in the future investigate the trend of mangrove area change post lockdown.

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