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Vegetation health and its relationship with Organic Pollution of the Santa Rosa Wetland, Chancay – Lima, 2023

[Salud de la vegetación y su relación con la Contaminación Orgánica del Humedal Santa Rosa, Chancay – Lima, 2023]

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Resumen

La presente investigación tuvo como objetivo: Determinar la Salud de la Vegetación y su relación con la Contaminación Orgánica del Humedal Santa Rosa, ubicado en el distrito de Chancay, en el año 2023. El estudio es de tipo mixta, de un nivel descriptivo al analizar imágenes de satélite para determinar los índices de vegetación de diferencia normalizada (en inglés, NDVI), con un diseño experimental, al tomar muestras de agua y ser analizadas en laboratorio, para identificar los niveles de contaminación por material orgánico. Resultados: Del análisis realizado por imágenes de satélite se determinó que el NDVI disminuyo en el año 2023, (valor de 0.132) entre los meses de junio a octubre, y en el análisis de la calidad del agua se midieron los parámetros de demanda química de oxígeno, cuyos resultados se encuentran entre los valores de 48.50 a 100.50 mg/L, solidos suspendidos totales de 30 a 31 mg/L y la demanda bioquímica de oxígeno entre 19.34 a 33.50 mg/L indicando que existe contaminación (DS. N° 004-2017-MINAM), a la vez se hizo una reafirmación de los resultados midiendo la extensión de la vegetación con un análisis de clasificación supervisada con las imágenes de satélite obteniendo que la vegetación del humedal (legua y lenteja de agua) aumentaron de 66.08% a 86.64% entre los meses de junio a octubre. De acuerdo con los datos obtenidos se concluye que existe relación entre ambas variables si la contaminación disminuye la vigorosidad de las plantas indicadores también disminuye ya que están actúan biológicamente como fitorremediadoras.

Palabras clave: Humedal, Imágenes de Satélite, Índice de vegetación de diferencia normalizada.

Abstract

The present research aimed to: Determine the Health of Vegetation and its relationship with Organic Pollution of the Santa Rosa Wetland, located in the district of Chancay, in the year 2023. The study is of a mixed type, with a descriptive level by analyzing satellite images to determine the Normalized Difference Vegetation Index (NDVI), with an experimental design, by taking water samples and analyzing them in the laboratory to identify the levels of organic material pollution. Results: From the satellite image analysis, it was determined that the NDVI decreased in 2023, (value of 0.132) between the months of June to October, and in the water quality analysis, the parameters of chemical oxygen demand were measured, with results ranging from 48.50 to 100.50 mg/L, total suspended solids from 30 to 31 mg/L, and biochemical oxygen demand between 19.34 to 33.50 mg/L, indicating that there is pollution (DS. N° 004-2017-MINAM). At the

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same time, the results were reaffirmed by measuring the extent of the vegetation with a supervised classification analysis of the satellite images, obtaining that the vegetation of the wetland (duckweed and water lentil) increased from 66.08% to 86.64% between the months of June to October. According to the obtained data, it is concluded that there is a relationship between both variables; if pollution decreases the vigor of the indicator plants also decreases as they act biologically as phytoremediators.

Keywords: Educational wetland, Satellite images, Normalized Difference Vegetation Index.

1. Introduction

Wetlands are essential for life, they have a significant environmental value as ecosystems, due to their diversity of flora and fauna (Yupanqui, 2019), since they are home to many characteristic biological communities, in addition to the ecosystem and hydrological services they provide, some being such as nutrient retention, water regulation and carbon storage, in addition to benefits to the population such as forage, fish, among others (Barbier, 2018, as cited in Martínez et al., 2021). In this way, the man-nature relationship coexists, obtaining a positive productive side, however, despite their ecosystem importance, wetlands are impacted by human activity, which is very noticeable, some of its causes being urban growth, excessive exploitation of their resources and dumping of contaminated water into their sources, this has led to more fragile ecosystems, Millennium Ecosystem Assessment, 2005, as cited in Apeño (2020). Various factors cause the degradation of ecosystems in Peru, the fragile institutions of the State to guarantee the protection and adequate management of wetlands are among these reasons.

The wetlands of the Central Coast are part of a biological corridor of migratory birds on the desert coast of Peru (Regional Government of Lima, 2017), however, industries and urban areas, in an uncontrolled and disorderly manner, do not comply with environmental policies. bringing with it irreversible damage. A clear example, in one of the wetlands considered a Regional Conservation Area, the zoning of a land located in the buffer zone has been modified to “light industry”, affecting resident and migratory birds that seek refuge in these ecosystems.

In the district of Chancay, the Santa Rosa Wetland is located, also known as El Cascajo, it is an ecosystem that has great ecological value, of the more than one hundred species of vascular plants, it stands out for having a high richness of vascular flora (Gonzales et al., 2019) and an important variety of fauna species, 73 bird species reported; Being one of the most representative of the Peruvian Coast, however, it is considered one of those with the highest number of invasive species compared to other coastal wetlands, being a great threat to the diversity of species present. In its surroundings there are agricultural areas, which affects aquatic species due to the contribution of nutrients through runoff, bringing with it other characteristic species due to their population density covering almost the entire wetland. Likewise, overgrazing by sheep and cattle is harmful. Urban and industrial growth makes it difficult to determine certain measures necessary to improve the protection of the wetland and eradicate sources of pollution (Zamora, 2019). Furthermore, the construction of the Chancay megaport is an environmental problem that has caused prejudice to nature; this project has demolished a large part of Cerro El Cascajo, this hill being a protection for the Santa Rosa wetland, located 180 m from the project. On the other hand, it is evident that the birds are moving due to the disturbance caused by the megaport project. (La República Newspaper, 2022).

The Normalized Difference Vegetation Index (NDVI) is a widely used indicator to evaluate the health of ecosystems and vegetation, as it is based on the typical absorption and reflectance properties of vegetation in the red band of the electromagnetic spectrum. This is because vegetation tends to absorb visible light and reflect near infrared in large proportions. (Camas and

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Mamani, 2022, pp. 61); provides information on the quantity and quality of vegetation in a specific area. We will calculate the NDVI of the Santa Rosa wetlands from satellite images which can provide a quantitative measure of vegetation and its changes over time. This will lead to a better understanding of the effects of water stress, human activities and natural processes on wetland health and dynamics. The Santa Rosa Wetland faces risks due to human activities, such as the discharge of untreated wastewater, accumulation of solid waste, excessive grazing, among other activities (ANA, 2022).

In the studies carried out by Flores et al. (2020) had the objective of defining, identifying and characterizing the transformations of the vegetation cover using satellite images such as WorldView 3 and CBERS2, they analyzed the changes in the vegetation cover of the Pantano de Villa from 2004 to 2018 using the NDVI. The methodology integrated image generation, geometric correction, and classification using ARGIS software, supported by field trips. Eight vegetation units were identified, and significant changes were observed, such as an increase in the area without vegetation and a decrease in areas of dense vegetation. These results highlight how land use change, mainly due to human activities, has negatively impacted wetland vegetation cover, underscoring the importance of appropriate conservation and management measures to protect these vulnerable ecosystems and their associated ecosystem services.

Camas and Mamani (2022) had the objective of evaluating the Ventanilla Wetlands Regional Conservation Area (RCA) and its buffer zone from before its creation until 2021, using remote sensing tools such as ICEDEX and NDVI to analyze the vegetation and soil saturation. The results revealed a significant loss of saturated soils, especially in the northern area of the ACR, while a gain was observed in the coastal strip. Regarding vegetation, a predominant gain was recorded in the coastal strip and losses in the limits of the ACR. These findings suggest a eutrophication process possibly attributable to human activities, highlighting the need to intensify conservation efforts to protect this ecosystem. This analysis demonstrates the usefulness of remote sensing in monitoring environmental changes and highlights the importance of additional measures to safeguard the integrity of the ACR.

Gonzales et al. (2019), in their article sought to update the list of vascular plants of the Santa Rosa Wetland and evaluate the changes in their floristic composition during the last 10 years. To do this, a four-quarter sampling was carried out using standardized collection and herbification methods. A total of 57 species were identified, it was found that 97% of the species were herbaceous and 60% were considered potentially invasive, in addition 30 historically recorded species were not found in this sample. The results suggest changes in the vascular flora of the wetland that may have been influenced by anthropogenic factors.

According to the National Service of Protected Natural Areas (SERNANP, 2022), wetlands are very important ecosystems for living beings, they provide multiple natural resources such as water, food, medicines, among other benefits for subsistence. They fulfill important functions such as erosion control, support of the food chain, sediment retention and have a fundamental role in adaptation to climate change.

This study is carried out with the intention of providing information and knowledge about the current condition of the Santa Rosa Wetland. The research will allow us to analyze the environmental and territorial problems of the area and reach practical solutions that minimize significant impacts with the use of satellite images obtained from the EESA COPERNICUS and USGS platforms, which will allow us to determine the area of influence through the calculation of the NDVI. which allows observing the health of the vegetation and obtaining a diagnosis of the change of the wetland, this will be corroborated by the analysis comparisons of the water samples taken in the wetland.

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The results of the analysis of the samples will provide valuable information on organic contamination in the Santa Rosa Wetland and be able to observe whether this contamination is associated with the growth or decrease of the vegetation cover of the wetland. Thus being very useful for local authorities and affected populations, as it will allow them to take strategies to protect and restore this important aquatic ecosystem.

2. Materials and Methods

This research has a mixed approach, since quantitative and qualitative approaches will be taken into account. Being a non-experimental design of a descriptive type, since opinion surveys will be used that will give us an overview of the phenomenon to which we refer and at the same time it will have an experimental design since samples will be taken “in situ”, that will be analyzed in the laboratory to obtain results on the proposed variables (Hernández et al., 2014).

The study was carried out in the Santa Rosa Wetland known as El Cascajo. According to the regulations referring to the classification of bodies of water described by D.S. N° 015-2015 MINAM, belongs to Category 4, which indicates that it is about conservation of aquatic environments that form fragile ecosystems, which require conservation attention and subcategory E1, is made up of lakes and lagoons including wetlands, It has an area of 21.04 hectares with a perimeter of 2,360.88 meters.

2.1. Universe and sample

The study area is developed on the Santa Rosa Wetland, located in the district of Chancay, Huaral province of the department of Lima, where the Environmental Conservation Area (ACA) Santa Rosa Wetland - Chancay has been selected as our universe, with an area of 874,927.67 m^2, established by Municipal Ordinance No. 013-2020-MPH-CM of the Provincial Municipality of Huaral, considering the sample (unit of analysis) to be the purely Wetland area represented by the sheet of water and zones humid which has an area of 210,414.96 m^2.

Figure 1. Location Map of the Santa Rosa Wetland study area.

2.2. Procedure

The first step was to identify the health of multi-temporal vegetation using the Normalized Difference Vegetation Index (NDVI) instrument, which is an indicator used to evaluate the health of ecosystems and vegetation (Martínez et al., 2021). providing information on the quantity and quality of vegetation in a given area. For their respective calculation, a compilation of the available satellite images that have a percentage of less than 10% of cloud cover was made, to have a better view of the study area. In this case, Sentinel-2 images with a resolution of 10 m were used.

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We selected the satellite images for the indicated dates and each of them were processed using the ArcGIS software. Then, band 8 (B8) and band 4 (B4) were combined, obtaining a raster image of values from -1 to 1, these values mean that the value closest to -1 indicates vegetation in poor condition while values close to 1 indicate vegetation in good condition, according to the raster values they are categorized as: dead plant, diseased, moderately healthy and very healthy. We adapted this classification to the wetland area and valued each range within the area to be able to calculate the corresponding area of each NDVI range, showing the procedure in Figure 2.

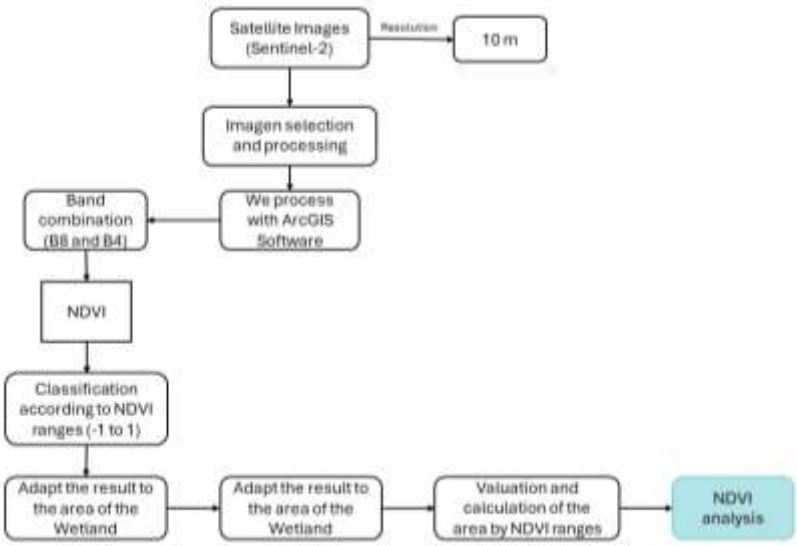

Figure 2. Procedure for NDVI Calculation

To determine the organic contamination of the wetland, analyzes of the COD, DO, BOD5 and TSS parameters were carried out, taking water samples from the wetland and analyzing them in the laboratory, for this the following has been taken into account:
For the analysis of the chemical oxygen demand (COD), the 100 mL sample is brought to a boil with reflux in the presence of mercury sulfate to avoid interference from chlorides. The tubes were placed in the block digester at 150ºC for two hours, after cooling to room temperature, the plugs are removed and two drops of ferroin are added, stirred with a magnetic stirrer while titrated with 0.01 N Mohr's salt. Finally, it is refluxed and begins to titrate two blanks containing the reagents and a volume of distilled water as well as the sample.

$$COD \text{ en mg } O_2/L = (A - B)*N*8000*F / \text{Sample volume (mL)}$$

Where:
Sample volume (mL)
A are the mL of titrant used for the blank
B are the mL of titrant used for the sample
N is the normality of the titrant
F is the sample dilution factor
N is equal to [volume of dichromate (mL) * 0.1] / volume of salt spent in the titration.

For Dissolved Oxygen (DO), the method applied for the analysis was electrometric, the calibration of the equipment was necessary and the readings were carried out on the samples according to the procedure: first introduce the electrode previously washed with water to the sample, then

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shake uniformly and read the oxygen concentration directly from the instrument. Finally, DO concentrations are taken directly from the instrument reading.

For the biochemical oxygen demand (BOD5), it is necessary to prepare the water to dilute the sample using a bag of BOD nutrient buffer solution (biochemical oxygen demand), proceed to measure six portions of well-mixed sample with a serological pipette and transfer them to separate 300 mL BOD bottles with glass stoppers, fill each bottle up to the top with seeded dilution water, when adding the water, let it fall slowly down the sides of the bottle to avoid formation of bubbles, then cover the bottle, taking care not to trap any air bubbles, and tighten the bottle cap with your finger; then invert the bottle several times to mix. After that, add enough dilution water to the spout of the BOD bottle to form a water seal, placing a plastic cap on the spout of each bottle and placing the bottles in an incubator at 20 ± 1°C. Finally, incubate in the dark for five days. When the incubation period has been completed, determine the dissolved oxygen content (mg/L DO remaining) in each bottle, using a dissolved oxygen probe.

For the analysis of total suspended solids - TSS, the filter must be installed in the equipment and the vacuum must be started and rinsed with distilled water, continuing until the remains of water are eliminated, then remove the filter and place it in the oven at 103 -1050°C X 60 min. Subsequently, take the filter to the desiccator and then determine the weight of the filter. Repeat the analysis until the filter weight is constant.

Finally, to identify the relationship between the health of the vegetation and organic contamination will be provided by the NDVI analysis and the organic analyzes of the water sample, for this satellite images of the Copernicus and Sentinel Hub platforms will be searched, these Free access images will be downloaded and analyzed using a GIS program, obtaining the values of the vegetation indices, this will be temporarily corroborated how the wetland was in the aspect of organic contamination, this information will be determined by the environmental quality standards for water, (D.S. N° 004-2017-MINAM, 2017), category 4 Conservation of the aquatic environment of lakes and lagoons.

3. Results

3.1. Wetland vegetation health

It has been measured according to the NDVI index, presenting values from -1 to +1, negative values mean that the vegetation is in problems, while positive values refer to vegetation in good health; with 20 x 20 m Sentinel images. resolution, were used to determine the NDVI for the months of June, July and October 2022 and 2023, obtaining the following result:

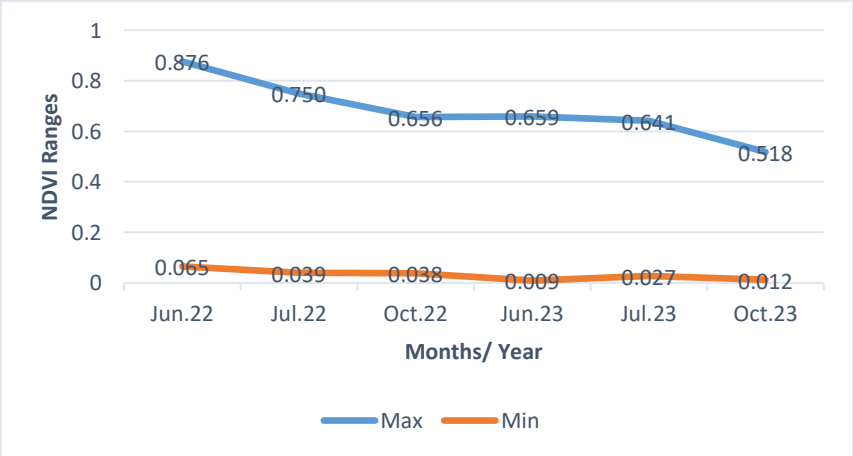

Figure 3. NDVI values

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As can be seen in Figure 3, the levels of the NDVI index begin to decrease from June 2022 to October 2023. These results have been obtained given that the water analyzes were carried out in these months (2023) and a comparative with the health of the vegetation in the same months of 2022.

3.2. Organic wetland pollution

It was determined by the analysis of water samples obtained in situ, in this sense four types of analysis were used: chemical oxygen demand (COD), dissolved oxygen (DO), biochemical oxygen demand (BOD5) and total suspended solids (TSS).

According to the results obtained, the DO in water, which is an indicator of how much liquid oxygen bodies of water have and is vital for the survival of aquatic species, obtained values ranging from 3.80 to 6.00 mg/L, according to the environmental quality standards described in D.S. No. 004-2017 (Category 4), it must be greater than 5, in this sense as of July this value exceeded the quality standards.

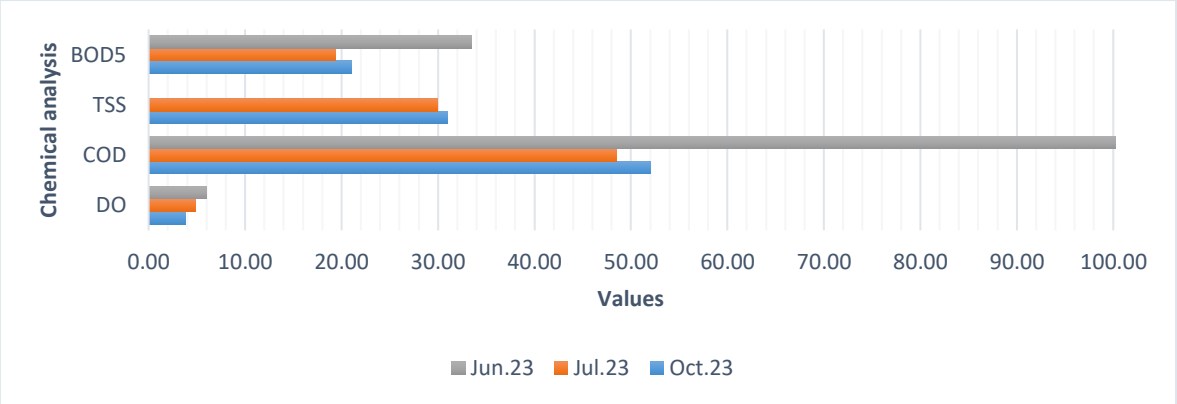

Figure 4. Water analysis values of the Santa Rosa Wetland, 2023

The COD analysis in Figure 4 was carried out to know the amount of oxygen that a body of water requires to oxidize organic matter, a product of wastewater contamination. According to the analyzes of the water samples, the values are between 48.50 to 100.50 mg/L, for our Peruvian legislation there are no maximum permissible limits for this indicator, however, the Aguanova laboratory in Spain (2023), states that The COD limits must be the following: for pure water from 0 to 20 mg/L, slightly contaminated water from 20 to 100 mg/L, moderately contaminated water from 100 to 500 mg/L, highly contaminated water from 500 to 3,000 mg/L and extremely contaminated water with 3,000 mg/L. So we would be dealing with slightly contaminated waters. The BOD5 indicator provides us with information on the amount of oxygen required by a heterogeneous microbial population to oxidize organic matter in a period of five days (DOF, 2001). According to the values obtained from water analyses, it varies from 19.34 to 33.50 mg/L, according to our standard this index must be at a value of 5 mg/L, the high values of the results indicate the high concentration of organic matter, due to the presence of microorganisms such as fungi, plankton and bacteria. SST analysis refers to the particulate material that is suspended on the surface of a sheet of water. In the analysis of water samples in the Santa Rosa lagoon, values of 30 to 31 mg/L were obtained, according to our Normatively, these values must be equal to or less than 25 mg/L. This indication is attributed to the fact that the wetland is surrounded by precarious homes that do not have a good sewage system.

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These data are also projected by the population, since in the opinion survey 51.6% of the participants reported that the main activity that disturbs the ecosystem of this wetland is garbage, followed by the megaport with 29%. Regarding the interest of the municipal authorities in conserving the wetland, 67.7% stated that the authorities do nothing for the conservation of this place, 48.4% stated that the wetland is in a bad state and finally, 29% They believe that the biggest pollutant in the wetland is produced by people's waste, followed by factory waste.

3.3. Relationship between vegetation health and organic pollution of the wetland

The relationship is to indicate whether the greater the contamination of the water by organic waste, the greater or lesser the health of the vegetation in the lagoon. This vegetation will be represented mostly by water lettuce (*Pistia stratiotes*) and duckweed (*Lemna minor*), these species are indicators of eutrophication, this process means the deterioration of water quality, mainly due to the enrichment of nitrogen and phosphorus (Ledesma et al., 2013). In figure 5 (left) we can see that the NDVI values began to decrease according to the dates from June to October 2022 and 2023. This decrease indicates that the vigor began to have lower values (+1), which means that the quality of the wetland water begins to improve, while in Figure 5 (right) the wetland water quality indices decreased drastically between the months of June and July and then rose in small proportions, this happened in the BOD5 and COD, whose indicators specify the contamination of the wetland by organic material, when descending, indicate that the biological functions of aquatic plants have generated phytoremediation of the wetland, removing its contaminants (Mendoza et al., 2018).

In this sense we can indicate that there is a relationship between the health of the vegetation (vigority) and the quality of the water (pollution) of the Santa Rosa wetland. To reaffirm the results, the wetland was subjected to a supervised classification analysis, which consists of evaluating the presence of vegetation through satellite images and control points, in this sense the following results were obtained.

Figure 5. Image of the vegetation of the Santa Rosa Wetland. June 2023 (left) and July 2023 (right) and their extension of the water sheets.

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Figure 6. Image of the vegetation of the Santa Rosa Wetland (2023)

According to the results of the supervised classification of the lettuce and duckweed species, they obtained an extension of 66.08%, 73.32% and 86.64% in the months of June, July and October respectively (see Figure 5 and 6), the increase in the population of these species indicates that they had greater phytoremediation actions, which adjusts to the BOD5 and COD measurements of the months of July and October.

4. Conclusions

The NDVI values provide us with the state of the health of the vegetation. These analyzes carried out at the Santa Rosa Wetland in the years 2022 and 2023 indicate that it has decreased, in the year 2022 the difference between June and October was 0.220 and in the year 2023 had a value of 0.132, it decreased in both periods. The contamination of the wetland was measured by the quality of its waters, in this sense analyzes were carried out on the samples collected, obtaining that the COD parameter is between 48.50 to 100.50 mg/L, according to our standard it does not indicate maximum permissible limits, but The Aguanova laboratory indicates that it is slightly contaminated water, in the same way the SST parameters resulted with values of 30 to 31 mg/L, when our regulations indicate that they should not be greater than 25 mg/L and the BOD5 were obtained values of 19.34 to 33.50 mg/L, when the regulations indicate that they must have a value of 5 mg/L, in this sense we have contaminated water and between the months of June to July it decreased, but in this last month it began to increase. From the analyzes carried out it can be understood that there is a relationship between both variables, if pollution decreases the vigor of the indicator plants also decreases since they act biologically as phytoremediators. In this sense, the health of the wetland vegetation decreased between the months evaluated from June to October, these months were selected considering that in this period of time the wetland water analyzes were carried out in the years 2022 and 2023 to see its difference, which indicates that in 2022 this index decreased by a greater value (0.220) compared to the year 2023 (0.132), indicating more severe contamination.

With respect to the contamination of the waters of the Santa Rosa Wetland, measurements were made on the parameters of BOD, TSS and BOD5 in the year 2023, according to the analyzes the BOD obtained a value of 100.5 mg/L (June), 48.50 mg/L (July) and 52.0 mg/L (October), for the TSS parameter 30.0 mg/L (July) and 31.0 mg/L (October) were obtained, and the BOD5 parameter obtained values of 33.5 mg/L (June), 19.34 mg/L (July) and 21 mg/L (October), according to our regulations for the SST and BOD5 parameters, the values exceed the maximum

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permissible limits, for the quality of Category 4 Conservation of the aquatic environment, E1 Lagoons and lakes (D.S: N° 004-2017-MINAM).

A supervised classification was carried out (20 x 20 m Sentinel satellite images) to corroborate that there is a relationship between the NDVI variable and the Pollution of the waters of the Santa Rosa wetland, indicating that the values in percentage of the wetland increased from June to October (66.08%, 73.32%, 86.84%) whose rise means that they had greater phytoremediation action to the contamination of the wetland by organic material.

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