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Assessing the Accuracy of Vegetation Indices Using SoPI and Sentinel-2 Images: Case Study of the Loma Alta Reserve, Santa Elena

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Abstract — **This study aims to evaluate the accuracy of vegetation indices generated using the SoPI software, based on Sentinel-2 imagery collected between 2020 and 2024. Following a structured methodological framework, the process included the selection and acquisition of satellite images, image processing, generation of NDVI maps and histograms, spatial adjustment of outputs to the study area, and the subsequent analysis and interpretation of results. The NDVI was derived from spectral bands obtained through the Copernicus Open Access Hub, and the outputs generated with SoPI were compared with the official NDVI products available via the Copernicus Browser using histogram-based analysis. Furthermore, the temporal variability of vegetation indices was examined using four satellite images captured on distinct dates, focusing on the Loma Alta Communal Ecological Reserve, located in Santa Elena, Ecuador. This analysis aimed to identify correlations between the indices and seasonal vegetation dynamics characteristic of the region, while also contextualizing the findings in light of existing literature. Overall, the study contributes to vegetation monitoring efforts in protected ecosystems by validating the reliability and applicability of SoPI.**

Keywords: **NDVI; SoPI; Sentinel-2; Copernicus Open Access Hub; index comparison.**

Resumen — **Este estudio tiene como objetivo evaluar la precisión de los índices de vegetación generados mediante el software SoPI, a partir de imágenes satelitales Sentinel-2 recopiladas entre 2020 y 2024. Siguiendo un marco metodológico estructurado, el proceso incluyó la selección y adquisición de imágenes satelitales, el procesamiento de dichas imágenes, la generación de mapas NDVI y sus respectivos histogramas, el ajuste espacial de los resultados al área de estudio y, finalmente, el análisis e interpretación de los datos obtenidos. El índice NDVI fue derivado de las bandas espectrales obtenidas a través del portal Copernicus Open Access Hub, y los productos generados con SoPI fueron comparados con los índices oficiales disponibles en el navegador Copernicus mediante un análisis basado en histogramas. Además, se examinó la variabilidad temporal de los índices de vegetación utilizando cuatro imágenes satelitales capturadas en fechas distintas, con énfasis en la Reserva Ecológica Comunal Loma Alta, ubicada en la provincia de Santa Elena, Ecuador. Este análisis tuvo como finalidad identificar correlaciones entre los índices obtenidos y las dinámicas estacionales de la vegetación propias de la región, al tiempo que se contextualizaron los hallazgos en función de la literatura científica existente. En conjunto, los resultados del estudio contribuyen a los esfuerzos de monitoreo de la vegetación en ecosistemas protegidos, validando la fiabilidad y aplicabilidad del software SoPI.**

Palabras Clave: **NDVI; SoPI; Sentinel-2; Copernicus Open Access Hub; comparación de índices.**

I. INTRODUCTION

REMOTE sensing and vegetation indices are fundamental tools for environmental monitoring, especially in protected areas and ecologically sensitive regions [1]. Technological advancements and the growing availability of high-resolution satellite imagery—such as that provided by the Sentinel-2 missions [2], [3]—have significantly improved the capacity to assess vegetation cover with greater precision. Among the most widely used indices is the Normalized Difference Vegetation Index (NDVI), which enables the quantification of vegetation density and health by exploiting the reflectance properties of near-infrared and visible spectral bands [4].

The use of specialized software, such as SoPI, has facilitated the processing and analysis of large volumes of satellite data. SoPI is a user-friendly and efficient platform that has demonstrated its ability to generate NDVI outputs with a level of accuracy comparable to those produced by conventional platforms, such as the Copernicus Open Access Hub [5], [6]. Numerous studies have validated the effectiveness of NDVI in characterizing temporal vegetation variability and in establis-

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hing correlations between vegetation indices, seasonal cycles, and dominant climatic patterns [7], [8].

Furthermore, the integration of open-source platforms such as SoPI into environmental monitoring workflows enhances the potential for decentralized, scalable, and cost-effective decision-making in conservation contexts [9]. By enabling non-specialist users, local authorities, and academic institutions to access and process satellite-derived vegetation indices without reliance on high-end computational infrastructure, tools like SoPI contribute to the democratization of remote sensing technologies [10]. This inclusive paradigm is particularly advantageous in biodiversity hotspots and regions constrained by technical or financial limitations, where timely assessments of vegetation dynamics are essential for the sustainable management of ecosystem services, early detection of land cover changes, and the formulation of adaptive conservation strategies aligned with global sustainability frameworks [11].

Within this context, the present study evaluates the accuracy of the NDVI generated using the SoPI software and Sentinel-2 imagery for the Loma Alta Communal Ecological Reserve, located in Santa Elena, Ecuador, over the period 2020-2024 [12]. The analysis aims to examine the association between NDVI values and seasonal as well as climatic variations within the study area, thereby validating the applicability of SoPI as a tool for remote sensing applications in protected ecosystems [13].

The remote assessment of vegetation through such methodologies contributes not only to a deeper understanding of ecosystem dynamics but also offers a scientifically robust and accessible framework to support natural resource management and conservation planning efforts [14].

II. METHODOLOGY

This study follows a quantitative research design that integrates both theoretical and empirical methodologies, emphasizing satellite image processing and vegetation index analysis. The NDVI was generated from Sentinel-2 satellite imagery using the SoPI software [15].

Theoretical Methods:

- Deductive reasoning.
- Mathematical modeling.
- Spatial analysis theory.
- Comparative analysis.

Empirical Methods:

- Direct observation.
- Time-series analysis.
- Data validation.
- Cross-sectional comparative study.

The theoretical framework supported the selection and evaluation of spectral bands suitable for NDVI computation, facilitating the graphical representation of vegetation distribution and enabling temporal variability analysis within the study area. The SoPI platform was employed to process a large volume of satellite imagery, producing NDVI maps that accurately represent vegetation conditions.

The empirical component focused on the systematic collection and comparison of satellite imagery acquired on different dates. These datasets were validated against the NDVI values obtained from the Copernicus Open Access Hub, ensuring consistency and reliability of the outputs. This integrated methodological approach enabled a robust assessment of seasonal vegetation variability in the Loma Alta Communal Ecological Reserve, reinforcing the validity of the NDVI results and their alignment with official records and climatic patterns [16].

A. Geographical Location

The Loma Alta Communal Ecological Reserve is located in the province of Santa Elena, Ecuador, within the Chongón-Colonche mountain range. It is situated to the south of Machalilla National Park and approximately 50 kilometers from the canton of Valdivia, in Guayas Province. The study area comprises four rural communities: La Ponga, La Unión, Loma Alta, and El Suspiro (see Fig. 1).

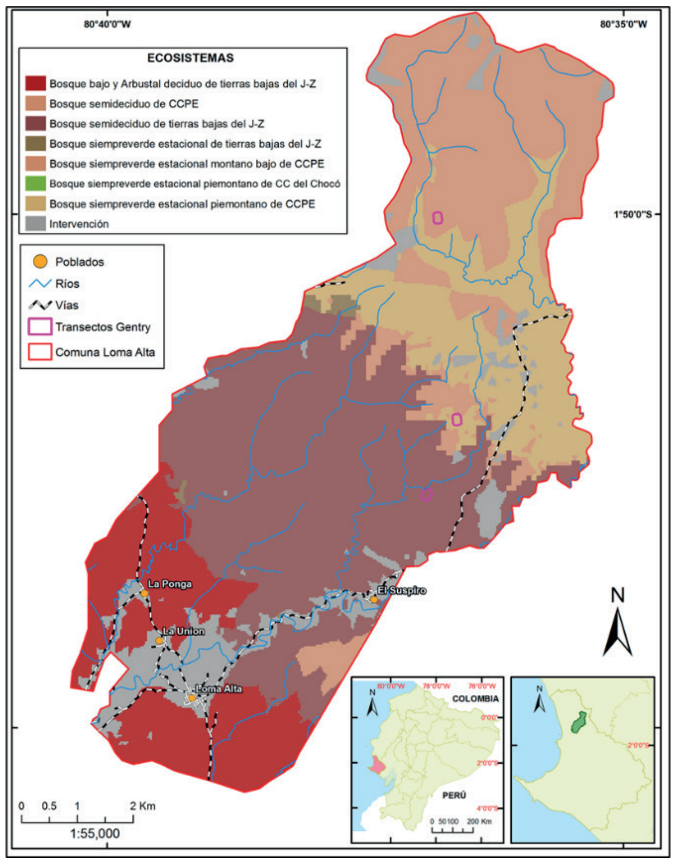

Fig. 1. Geographic location of the study area [17].

B. Base Data

The analysis was conducted using Sentinel-2 satellite imagery obtained from the Copernicus Open Access Hub, which facilitates the evaluation of temporal variability in vegetation indices within the Loma Alta Communal Ecological Reserve.

This region exhibits marked climatic seasonality, with two clearly defined periods: a rainy season, extending from December to May—peaking between January and March—and a dry season, lasting from approximately June to early December. During the rainy season, intense precipitation enhances vegetation development by providing essential moisture for plant growth. Conversely, the dry season, particularly between June and August, is characterized by a notable decline in rainfall, leading to reduced water availability and limited vegetative activity [18].

These precipitation patterns have a direct impact on vegetation dynamics, making it essential to monitor their variability throughout the year [19]. Sentinel-2 imagery offers high-resolution representations of these dynamics, enabling the derivation of vegetation indices such as the NDVI through the use of the SoPI software. These indices are essential for examining the relationship between vegetation behavior and seasonal climatic variability, and for assessing the accuracy and consistency of the outputs in relation to prior studies and historical climatic records [20].

C. Method for Generating NDVI Histograms and Images Using SoPI and the Copernicus Browser

This section outlines the methodological stages implemented for the acquisition, processing, and analysis of Sentinel-2 satellite imagery through the SoPI software and the Copernicus Browser. The objective was to generate NDVI outputs and their corresponding value-frequency histograms [21]. This procedure enables a rigorous evaluation of the accuracy of the NDVI values derived from SoPI and facilitates their direct comparison with official reference products generated by the Copernicus platform.

The methodological sequence is composed of six structured stages, as illustrated in Fig. 2.

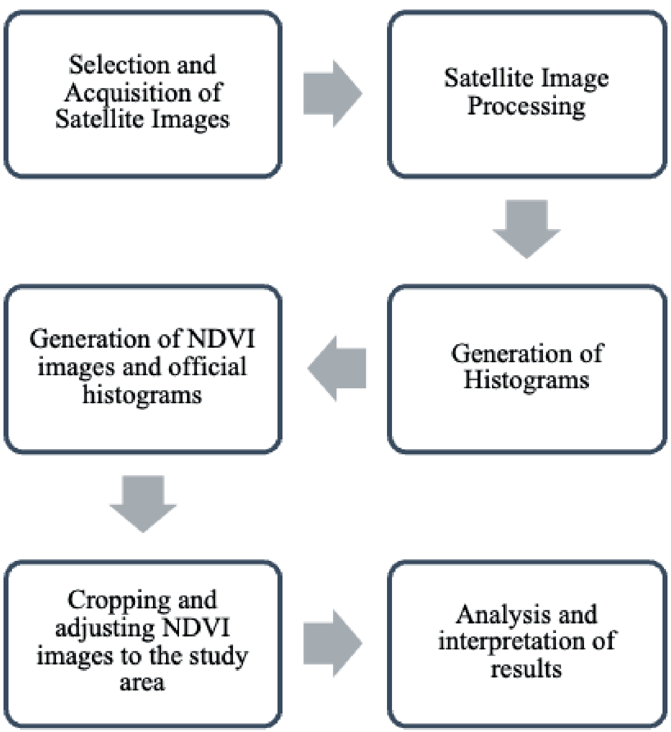

Fig. 2. Stages of the methodological procedure.

The methodological stages were implemented using the SoPI software and the Copernicus Browser, as previously detailed.

1) Selection and Acquisition of Satellite Images

Sentinel-2 satellite imagery was retrieved from the Copernicus Open Access Hub. The selection process followed clearly defined criteria, prioritizing scenes with less than 10 % cloud cover to minimize atmospheric interference that could distort surface reflectance values [3]. Furthermore, all selected images correspond to Level-2A products, which have undergone prior atmospheric correction. The spatial distribution and acquisition dates of the selected scenes are depicted in Fig. 3.

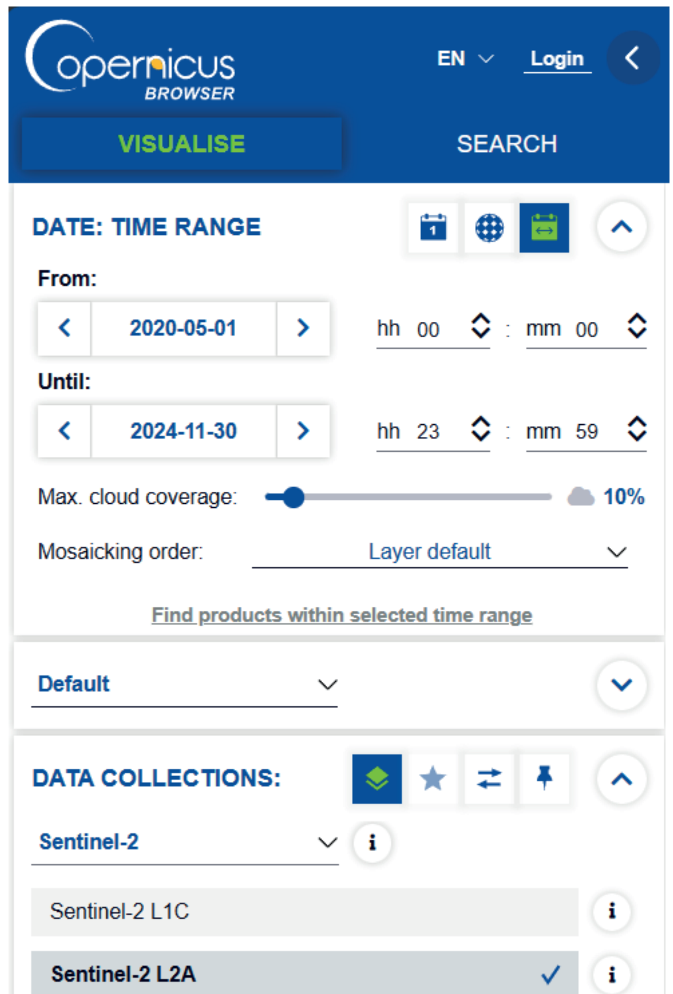

Fig. 3. Configuration used for acquiring Sentinel-2 imagery via the Copernicus Open Access Hub.

Sentinel-2 satellite scenes acquired on four specific dates —December 19, 2024; September 1, 2023; May 9, 2020; and October 11, 2020—were selected to characterize seasonal variability within the Loma Alta Communal Ecological Reserve. These dates were strategically chosen to represent distinct stages of the annual vegetation cycle (dry and rainy seasons), thus enabling a robust comparative analysis of NDVI values across contrasting seasonal conditions (see Fig. 4).

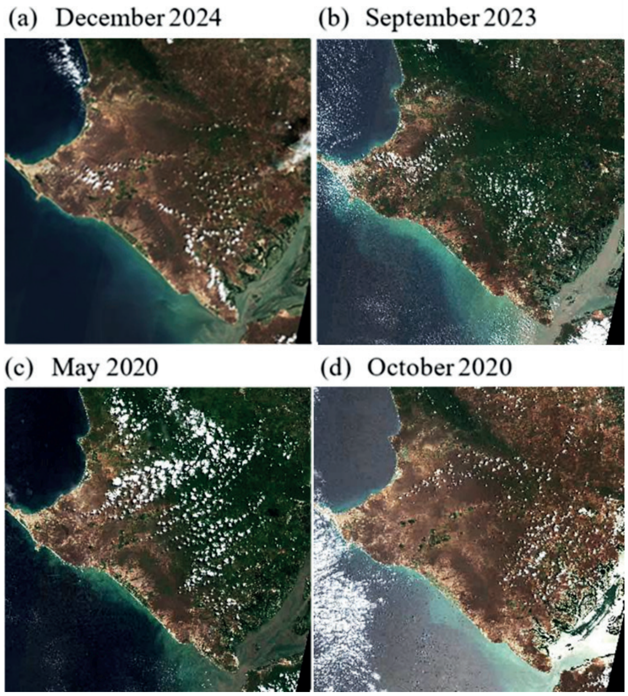

Fig. 4. Sentinel-2 imagery of the Loma Alta Communal Ecological Reserve acquired on different dates.

2) Satellite Image Processing

For each selected Sentinel-2 scene, the spectral bands necessary for NDVI computation—namely, the red band (Band 4) and the near-infrared band (Band 8)—were extracted. All image processing procedures were performed using the SoPI software (hereinafter referred to as SoPI) [22].

a) Image and Band Loading in SoPI

The Sentinel-2 scene and its corresponding spectral bands—Band 4 (red) and Band 8 (near-infrared)—were imported into the SoPI software for subsequent processing (see Fig. 5).

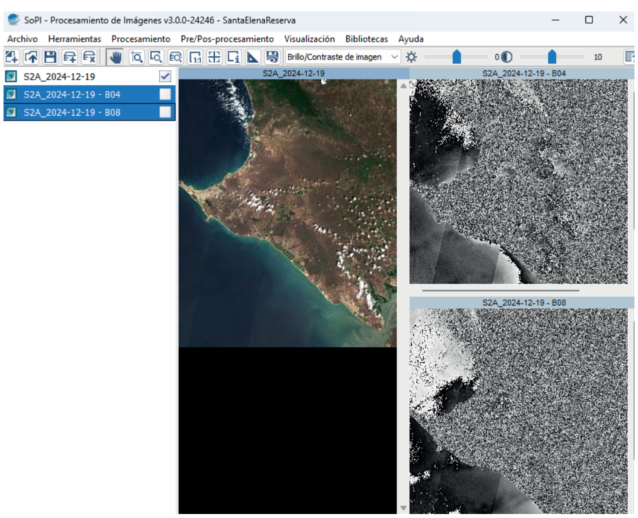

Fig. 5. Image processing - loading image and bands.

b) Band Stacking Procedure

To create the composite image, Bands 4 and 8 were activated, and the Band Stacking tool available in the SoPI interface was executed to merge them into a single dataset (see Fig. 6).

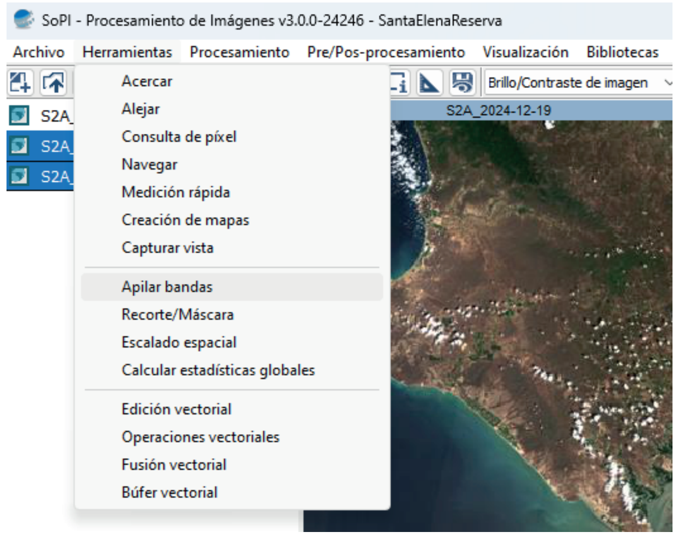

Fig. 6. Band stacking tools available in the SoPI interface.

The resulting stacked image is presented in Fig. 10, accompanied by the corresponding .TIF file generated for subsequent NDVI computation, as shown in Fig. 7.

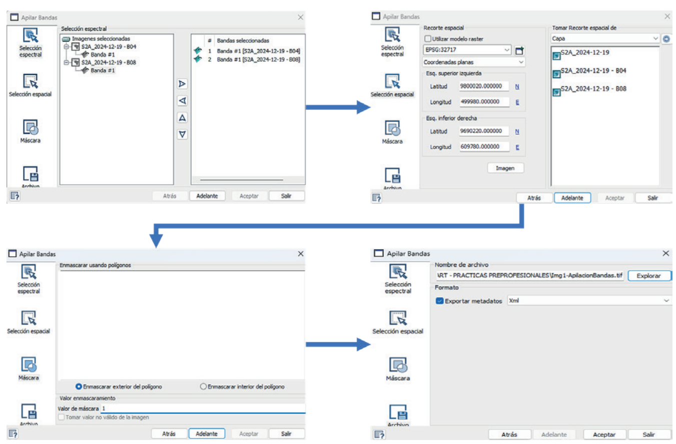

Fig. 7. Band stacking process executed in the SoPI interface.

The final stacked image, resulting from the band combination process, is displayed within the SoPI interface and stored as a georeferenced .TIF file for subsequent NDVI analysis. This product consolidates the spectral information required for vegetation assessment and ensures spatial consistency across bands. The visual output and associated .TIF file are shown in Fig. 8, highlighting both the true-color composite and the radiometric content available for processing.

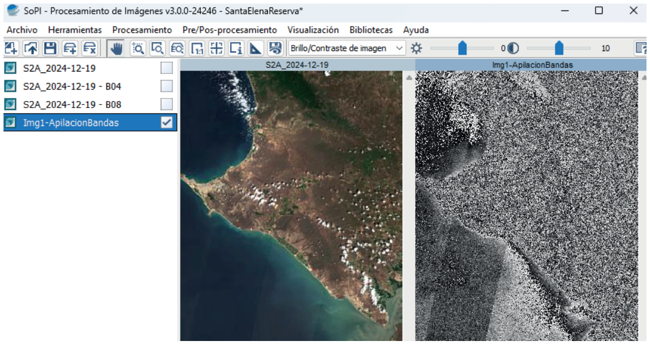

Fig. 8. Stacked image and associated .TIF file.

c) NDVI image generation

The NDVI image was computed from the stacked bands using the Standardized Indices module in SoPI (see Fig. 9).

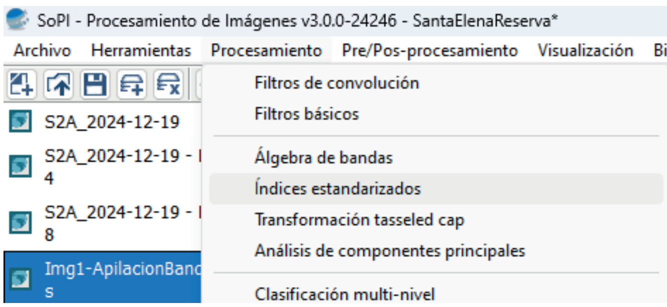

Fig. 9. Standardized indices module in SoPI.

The NDVI was computed using the classical formulation proposed in early remote sensing literature [9]. Specifically, the red band (Band 4) and the near-infrared band (Band 8) from Sentinel-2 imagery were used as input parameters for the index calculation. This procedure generated a new GeoTIFF file containing the NDVI values for the selected date (see Fig. 10), which served as the basis for subsequent spatial analyses.

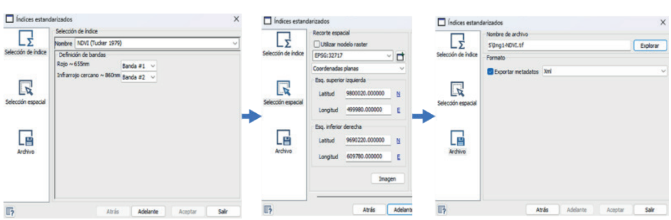

Fig. 10. NDVI generation process in SoPI.

d) Processing the complete dataset

The procedure described above was systematically applied to all Sentinel-2 satellite images included in the study to ensure consistency in data processing (see Fig. 11).

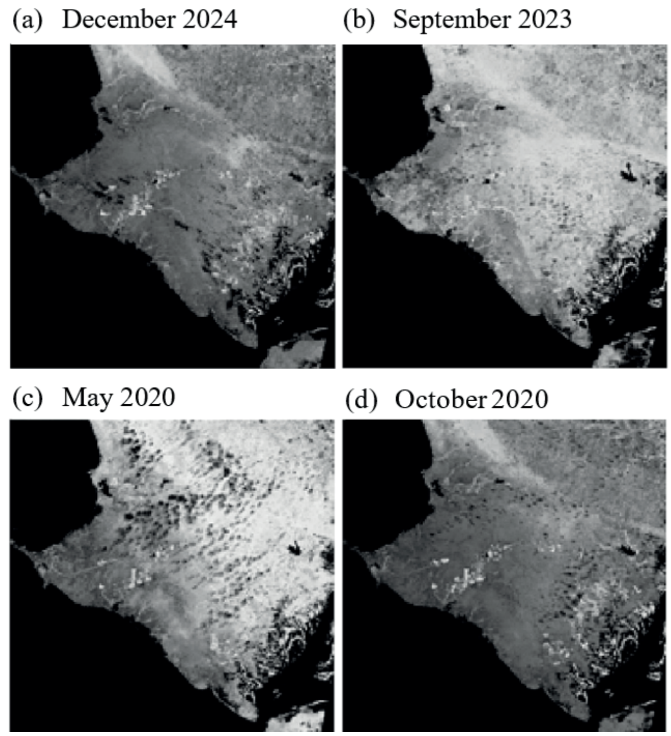

Fig. 11. NDVI maps generated for four different dates using SoPI.

3) Generation of Histograms

For each NDVI map generated, a corresponding histogram was produced to analyze the distribution of vegetation index values throughout the study area.

a) Selection of the NDVI Image for December 2024

The properties of the NDVI image corresponding to December 2024 were examined using the SoPI interface, allowing for the evaluation of value distribution characteristics (see Fig. 12).

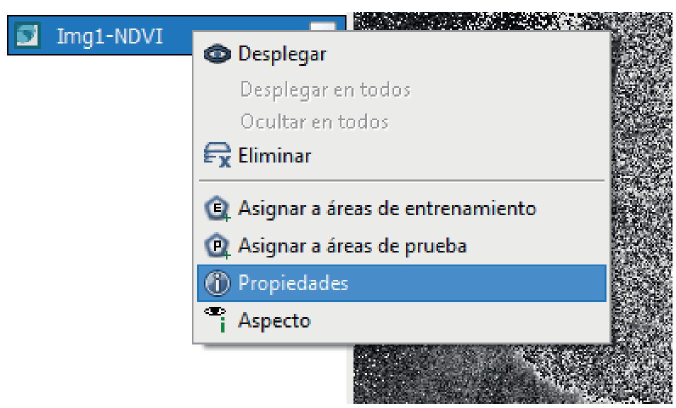

Fig. 12. NDVI image properties.

b) Histogram generation process

The histograms were generated from the NDVI outputs previously computed in SoPI. These graphical representations facilitated a detailed examination of the value-frequency distributions associated with each analyzed period, providing insights into the spatial and temporal variability of vegetation within the study area (see Fig. 13). The underlying NDVI values are derived from digital numbers (DN)—unitless pixel intensity values recorded by the sensor—which were subsequently converted into reflectance values during preprocessing. This procedure ensures consistency and comparability across acquisition dates and processing platforms.

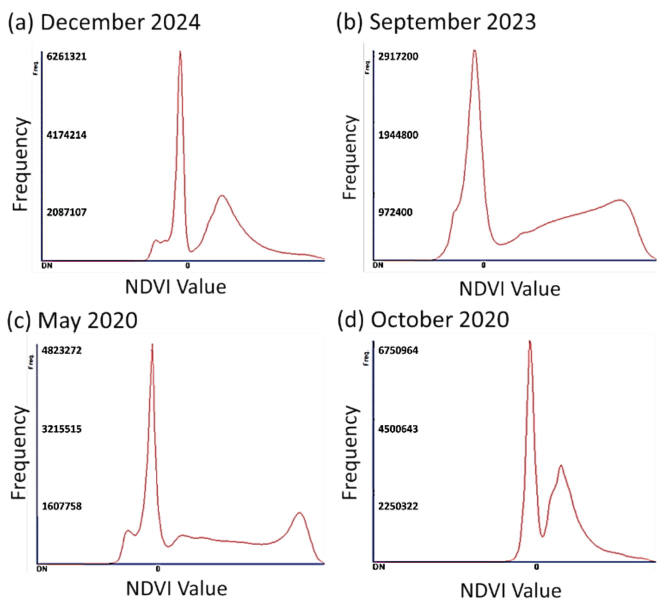

Fig. 13. Value-frequency histograms of NDVI values generated in SoPI for different acquisition dates.

4) *Generation of NDVI images and official histograms*

The NDVI outputs generated with SoPI were systematically compared to those produced using the official Copernicus Browser. This comparison involved configuring the Browser to apply the standard NDVI formula to the corresponding satellite scenes, followed by the extraction of histograms from the same geographic area to enable a direct comparative analysis [23].

For the December 2024 image, the same spatial extent was delineated in the Copernicus Browser. The NDVI layer was then created using the classical formula: NDVI = (NIR - R) / (NIR + R), by selecting the appropriate spectral bands available on the platform (see Fig. 14).

Once the visualization interface in the Copernicus Browser was fully configured, the histogram tool (see Fig. 15) was activated to display the distribution of NDVI values across the study area. This step facilitated an effective visual inspection of vegetation indices and enabled subsequent comparisons with the NDVI outputs generated by the SoPI software.

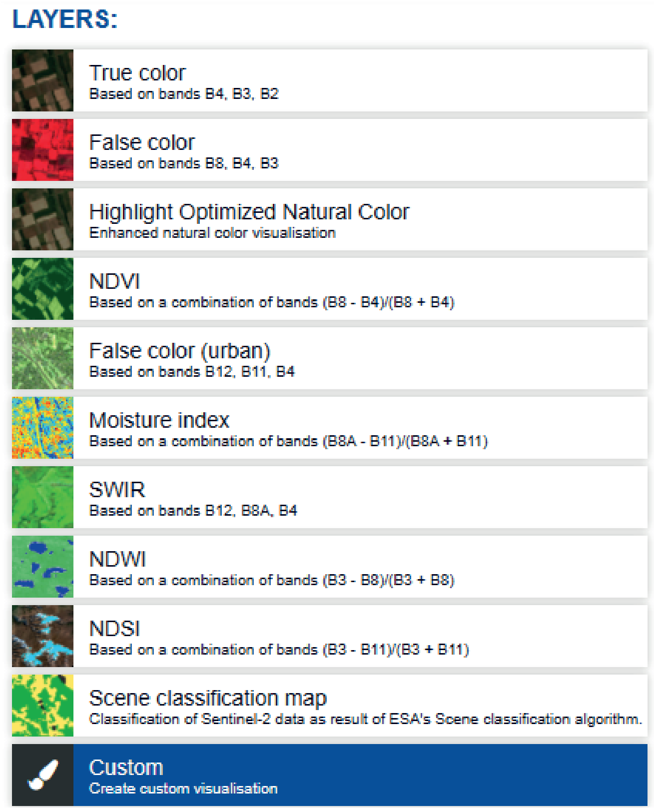

Fig. 14. NDVI configuration and histogram customization in Copernicus Browser.

Fig. 15. Histogram visualization tool in the Copernicus Browser interface.

Once the NDVI processing was completed using the Copernicus Browser, the platform's histogram tool was activated to visualize the distribution of vegetation index values for each selected acquisition date. This procedure enabled a graphical representation of NDVI frequency distributions, facilitating a structured analysis of the spatial and temporal behavior of vegetation across the study area. As illustrated in Fig. 16, NDVI outputs and their corresponding histograms were generated for four acquisition dates: (a) December 2024, (b) September 2023, (c) May 2020, and (d) October 2020. These visualizations were subsequently employed as a methodological reference for comparative assessment against the NDVI results obtained using the SoPI software.

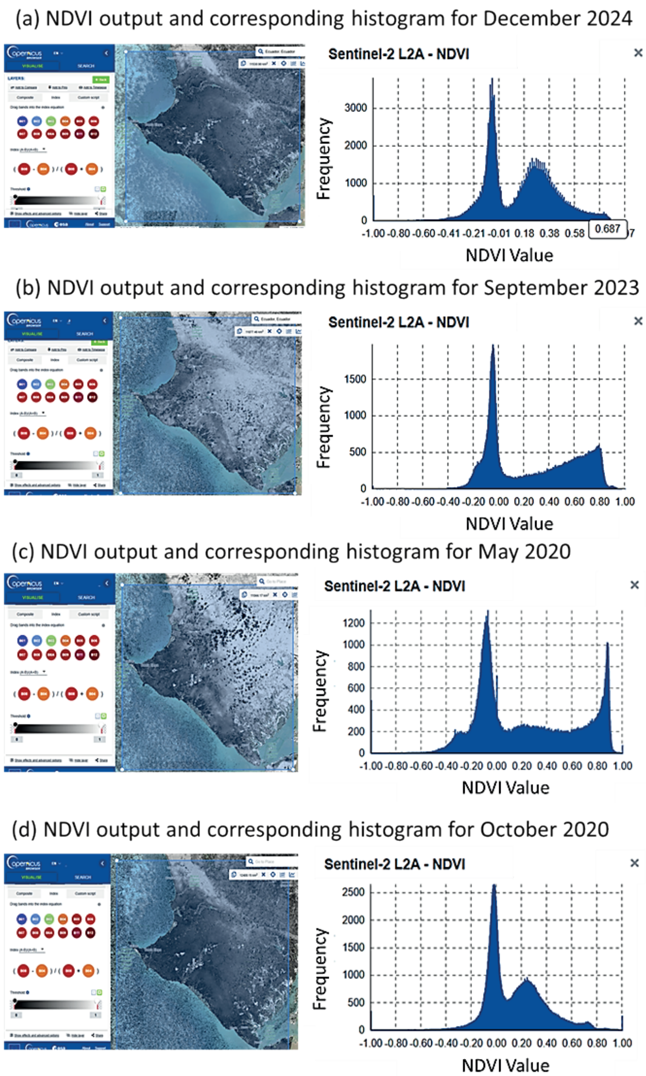

Fig. 16. NDVI visualization and histograms generated with Copernicus Browser for different acquisition dates.

5) Cropping and adjusting NDVI images to the study area

To enhance spatial accuracy for subsequent data analysis, the NDVI maps were geometrically corrected and clipped to conform precisely to the boundaries of the defined study area (see Fig. 17).

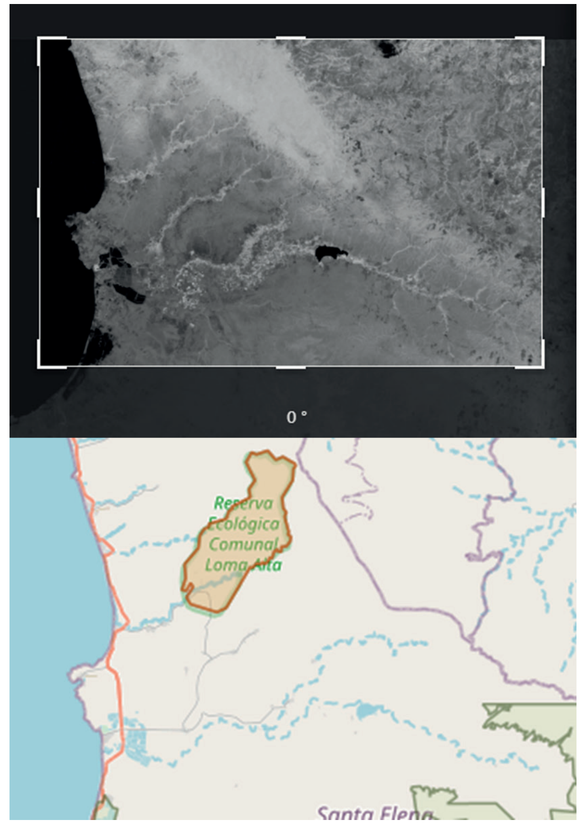

Fig. 17. Adjustment of the NDVI image to the boundaries of the study area.

Following the NDVI computation using the SoPI software, a series of outputs was generated to visualize vegetation cover for four selected dates. Fig. 18 illustrates the corresponding NDVI maps for (a) December 2024, (b) September 2023, (c) May 2023, and (d) October 2020. Each map is rendered in grayscale, where darker tones denote lower NDVI values and lighter tones indicate higher vegetation density. These visualizations were produced to support subsequent temporal analyses and enable cross-validation with the outputs generated via the Copernicus Browser. The procedure ensured consistency in formatting and processing parameters across all acquisition dates.

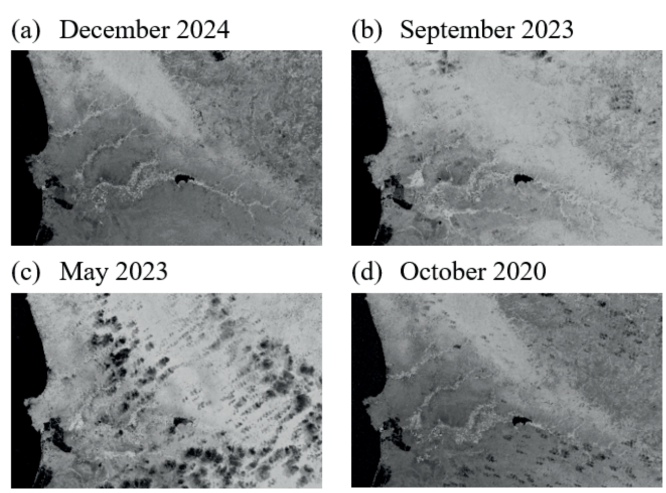

Fig. 18. NDVI images processed for the case study on different acquisition dates.

III. RESULTS

This section presents the final stage of the methodological process, focusing on the analysis and interpretation of the NDVI outputs. The results are based on a comparative evaluation of the NDVI values generated using the SoPI software and those obtained from the Copernicus platform.

A. Histogram Analysis

1) December 2024

- NDVI SoPI (see Fig. 19a): The histogram displays a relatively uniform distribution, with most values concentrated between 0,2 and 0,6. This interval reflects moderate vegetation cover across the study area during December 2024, aligning with expected seasonal patterns.
- NDVI Copernicus (see Fig. 19b): A similar distribution is observed, with values also clustered in the 0,2-0,6 range. Minor differences in the frequency peaks may be attributed to variations in preprocessing workflows or spatial resolution. Nevertheless, the overall consistency between both histograms supports the methodological robustness and cross-platform reliability of the NDVI extraction process.

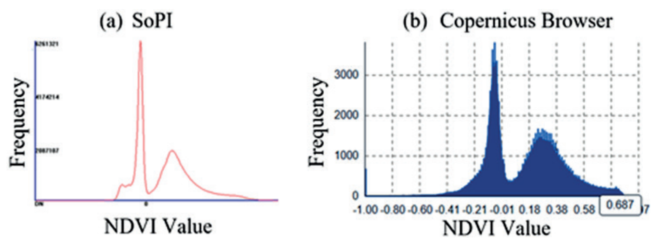

Fig. 19. Histograms – December 2024.

2) September 2023

- NDVI SoPI (see Fig. 20a): The distribution revealed predominant values ranging from 0,3 to 0,7, reflecting a relatively higher level of vegetation cover during this period, likely associated with increased moisture availability in the rainy season.
- NDVI Copernicus (see Fig. 20b): A comparable distribution was observed, with a more pronounced concentration of values between 0,4 and 0,6, suggesting consistency in vegetation density measurements, albeit with slightly sharper frequency peaks.

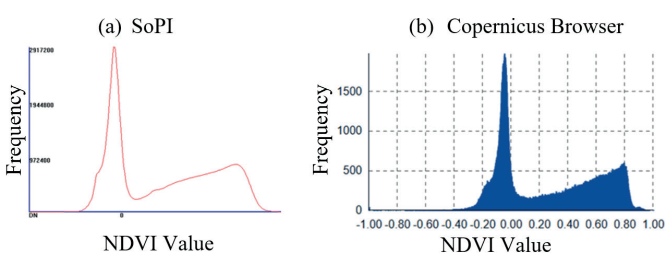

Fig. 20. Histograms – September 2023.

3) May 2020

- NDVI SoPI (see Fig. 21a): The values ranged from 0,1 to 0,5, reflecting low to moderate levels of vegetation density, consistent with the expected decline in plant cover during the dry season.
- NDVI Copernicus (see Fig. 21b): The distribution showed a similar trend, with predominant values between 0,2 and 0,5, supporting the coherence of the results across platforms and reaffirming the seasonal vegetation decline.

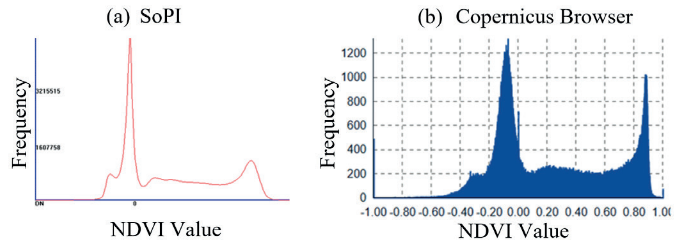

Fig. 21. Histograms – May 2020.

4) October 2020

- NDVI SoPI (see Fig. 22a): The predominant values ranged from 0,2 to 0,6, exhibiting a distribution pattern that closely mirrors the trend observed in December 2024, suggesting moderate vegetation coverage toward the end of the year.
- NDVI Copernicus (see Fig. 22a): A similar distribution was recorded, with minor deviations in the frequency of intermediate NDVI values, indicating strong consistency between both platforms during this period.

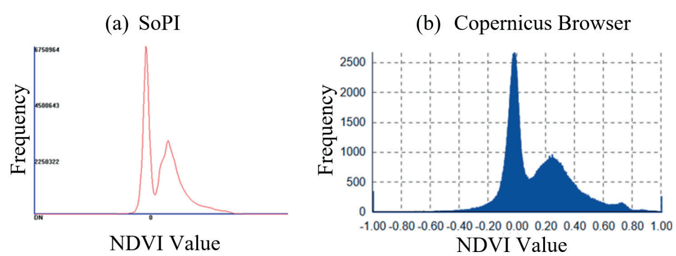

Fig. 22. Histograms – October 2020.

B. Comparison of NDVI SoPI and Copernicus

To quantitatively assess the relationship between the NDVI outputs generated by SoPI and those obtained from the Copernicus platform, the Pearson correlation coefficient was applied [23]. This statistical indicator evaluates the strength and direction of the linear relationship between two continuous variables and is mathematically defined in Eq. 1:

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (1)$$

Where:

- x_i and y_i represent the individual NDVI values from SoPI and Copernicus, respectively;

- $\bar{x}$ and $\bar{y}$ are the corresponding mean values for each data-set; and
- *r* ranges from -1 to 1, where values closer to 1 indicate a strong positive linear correlation.

To quantitatively assess the consistency between NDVI outputs generated by SoPI and the Copernicus Browser, Pearson correlation coefficients were calculated for each acquisition date using the NumPy library [24]. As illustrated in Fig. 23, the code snippet performs a comparative analysis between paired NDVI value arrays.

```
correlacion.py > ...
import numpy as np
ndvi_sopi = {
    "diciembre_2024": [0.2, 0.3, 0.5, 0.6, 0.4],
    "septiembre_2023": [0.3, 0.4, 0.6, 0.7, 0.5],
    "mayo_2020": [0.1, 0.2, 0.4, 0.5, 0.3],
    "octubre_2020": [0.2, 0.3, 0.5, 0.6, 0.4]
}
ndvi_copernicus = {
    "diciembre_2024": [0.21, 0.32, 0.52, 0.58, 0.42],
    "septiembre_2023": [0.31, 0.43, 0.61, 0.69, 0.51],
    "mayo_2020": [0.12, 0.22, 0.42, 0.48, 0.34],
    "octubre_2020": [0.22, 0.33, 0.51, 0.59, 0.41]
}

correlation_results = {}
for date in ndvi_sopi.keys():
    correlation = np.corrcoef(ndvi_sopi[date], ndvi_copernicus[date])[0, 1]
    correlation_results[date] = correlation

print(correlation_results)

PROBLEMS   OUTPUT   TERMINAL   PORTS   POLYGLOT NOTEBOOK   JUPYTER

{'diciembre_2024': np.float64(0.9952803422359229), 'septiembre_2023': np.float64(0.9975194459483209), 'mayo_2020': np.float64(0.9925232596048367), 'octubre_2020': np.float64(0.998585238621917)}
```

Fig. 23. Python algorithm used to compute the Pearson correlation coefficient.

The consistently high correlation values—ranging from 0,9925 to 0,9986—indicate a strong linear relationship between the two datasets. The highest concordance is observed in October 2020 (r = 0,9986), followed closely by September 2023 (r = 0,9975), underscoring the consistency of NDVI estimates irrespective of the sensor source. These findings confirm the reliability of SoPI as a robust and complementary platform for vegetation monitoring alongside the widely used Copernicus Sentinel-2 imagery.

TABLE I
PEARSON CORRELATION COEFFICIENTS
BETWEEN NDVI VALUES FROM SOPI AND COPERNICUS

Date	Correlation Coefficient (r)
December 2024	0,9953
September 2023	0,9975
May 2020	0,9925
October 2020	0,9986

To further evaluate the agreement between NDVI outputs from SoPI and the Copernicus Browser, scatter plots were constructed for each acquisition date (Fig. 24). The visualizations illustrate the linear relationship between the two datasets, with each point representing a paired NDVI value. A linear regression line was fitted to each scatter distribution, accompanied by a confidence interval to capture the spread of the data. The close alignment of data points along the trend lines reinforces the high correlation coefficients obtained previously, visually confirming the strong consistency across platforms.

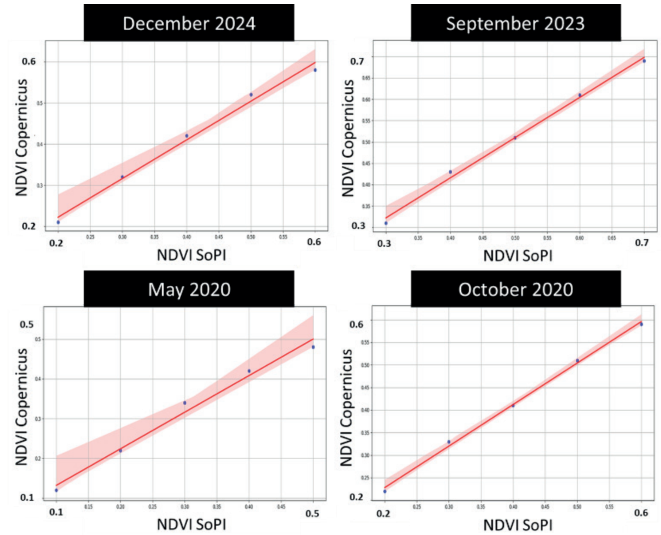

Fig. 24. Graphical representation of the correlation coefficients between SoPI and Copernicus NDVI values.

The NDVI values presented in Table II are dimensionless, as they result from a normalized ratio between near-infrared and red reflectance bands. This formulation enhances the interpretability of vegetation conditions, with index values ranging from -1 to 1. Higher values typically indicate dense, healthy vegetation, such as tropical forests or highly productive agricultural zones, while values near 0 are associated with sparse or non-vegetated surfaces. As a widely recognized ecological indicator, NDVI provides a robust means of quantifying vegetation dynamics across diverse environments.

TABLE II
AVERAGE NDVI VALUES AND SEASONAL CLASSIFICATION

Date	Average NDVI SOPI	Average NDVI Copernicus	Season
Higher Vegetation			
September 2023	0,50	0,55	Rainy Season
December 2024	0,40	0,41	Rainy Season (transition)
Lower Vegetation			
May 2020	0,30	0,34	Dry Season
October 2020	0,40	0,42	Dry Season (late stage)

IV. DISCUSSION

The comparison of NDVI histograms generated by SoPI and those derived from the Copernicus platform reveals a high level of consistency in the distribution patterns, reinforcing the effectiveness of SoPI as a reliable tool for vegetation monitoring. This consistency indicates that SoPI is capable of accurately replicating vegetation indices, which is essential for remote sensing applications, particularly in protected or ecologically sensitive ecosystems.

Minor discrepancies between the platforms may be attributed to differences in spatial resolution and processing parameters; however, such variations do not compromise the operational validity of SoPI. Additionally, divergences may result from the distinct algorithmic approaches implemented by each system, yet these differences do not significantly affect the consistency or interpretability of the outputs generated by SoPI [11].

Regarding seasonal variability, the NDVI values successfully reflect the temporal dynamics of vegetation cover in the Loma Alta Communal Ecological Reserve. Higher NDVI values, in September 2023 and December 2024 align with the rainy season, whereas the lowest values, recorded in May and October 2020, correspond to the dry season. These results demonstrate that SoPI effectively captures seasonal vegetation fluctuations and that its outputs correlate with climatic variability in the region. This underscores the value of continuous remote monitoring in understanding the relationship between vegetation patterns and environmental drivers [25].

Overall, the findings validate SoPI as a dependable, accessible, and scientifically robust platform for vegetation analysis and environmental monitoring in conservation-priority landscapes.

V. CONCLUSION

This study addressed a critical need in environmental monitoring by evaluating the accuracy of NDVI outputs generated using the SoPI software, with specific application to the Loma Alta Community Ecological Reserve. The core objective focused on generating, analyzing, and comparing vegetation indices derived from Sentinel-2 satellite imagery using SoPI and the Copernicus Browser as comparative platforms.

The methodological framework—based on satellite image processing, vegetation index computation, and histogram analysis—provided a robust foundation for assessing vegetation cover and seasonal dynamics in a protected natural setting. The use of SoPI, a user-friendly and accessible tool, enabled the processing of multispectral imagery and successfully replicated results comparable to those produced by more complex and conventional platforms.

Although minor variations were observed, mainly due to differences in algorithm implementation and image resolution, these did not significantly affect the reliability of the outputs or the patterns derived from the analysis. The NDVI values generated with SoPI accurately represented the seasonal behavior of vegetation, correctly identifying peak vegetation cover during the rainy season (September 2023 and December 2024) and reduced cover during the dry season (May and October 2020).

These findings confirm the potential of SoPI as an effective and affordable tool for monitoring vegetation dynamics, particularly in regions where technical and financial resources may be limited. Moreover, the information produced in this study provides valuable insights for strategic environmental management and conservation planning, contributing to the understanding of how vegetation responds to seasonal and climatic variability in ecologically sensitive zones.

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