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Analysis of the 2020 Godzilla Dust Event Over Puerto Rico

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Abstract

The Sahara Air Layer (SAL) transports large quantities of mineral dust from North Africa across the Atlantic Ocean, frequently affecting the Caribbean region. This study evaluated the impact of the June 2020 “Godzilla” Sahara dust event on satellite imagery over Puerto Rico using remote techniques. Satellite images acquired from Worldview were processed and analyzed in ENVI. Atmospheric correction was applied, and images collected during and before the dust event were compared to assess changes in spectral response and image quality. Visual analysis revealed reduced visibility, lower contrast, increased atmospheric haze, and washed-out colors during the dust event. Supervised classification methods, including Maximum Likelihood and Minimum Distance, and unsupervised classification methods, including IsoData and K-Means, were applied to identify and separate dust-related classes. Results demonstrated that Saharan dust significantly altered the spectral characteristics of the imagery and could be successfully identified as an independent class using both supervised and unsupervised approaches. Among the supervised methods, Maximum likelihood produced the most reliable classification results. This study highlights the effectiveness of remote sensing and image classification techniques for detecting and monitoring Sahara dust events over Puerto Rico.

Keywords: Sahara Air Layer (SAL), June 2020 Godzilla Dust Event, Puerto Rico, Remote Sensing, Satellite Imagery, Image Classification.

I) Introduction

The transport of Saharan dust across the Atlantic Ocean is a recurring atmospheric process that significantly influences environmental conditions in the Caribbean and the Americas. This atmospheric dust originates in the Sahara Desert, where strong surface winds lift fine (PM 2.5, PM 10) mineral particles into the atmosphere, forming the Saharan Air Layer. As the SAL travels westward, it interacts with regional weather systems, affecting cloud formation [2]. These processes can have wide-ranging consequences, including reduced air quality, impacts on human health, and changes in ecosystem productivity [1].

From a remote sensing perspective, Saharan dust presents a major challenge because satellite sensors are designed to measure surface reflectance under relatively clear atmospheric conditions. The presence of these large quantities of dust increases atmospheric scattering and absorption, which modifies the spectral signal recorded by satellite sensors. As a result, surface features such as vegetation, water bodies, and urban areas may appear spectrally altered in satellite imagery. The June 2020 Saharan dust outbreak, commonly referred to as the “Godzilla Dust Event,” was one of the most extreme events observed in the Caribbean in recent decades. The event was characterized by exceptionally high dust concentrations and widespread spatial coverage, making it an ideal case study for examining the effect of atmospheric dust on satellite observations. During this period, visibility across Puerto Rico was significantly reduced, and satellite imagery exhibited pronounced spectral distortion. These conditions provide as an opportunity to evaluate how different image classification approaches respond to extreme atmospheric interference.

The primary objective of this study is to assess how Saharan dust affects satellite imagery over Puerto Rico by comparing pre-event and during-event conditions in the month of June using

MODIS data. Specifically, this research examines changes in spectral data, visual characteristics, and classification performance under dusty atmospheric conditions. By evaluating both supervised and unsupervised classification techniques, the study aims to determine which methods are more effective in the presence of heavy atmospheric dust. Another goal is to determine which classification is more effective at identifying concentrations of dust on land and sea.

II) Methodology

2.1 Study Area

The island of Puerto Rico is part of the Greater Antilles, specifically located in the northeast of the Caribbean Sea (**Figure 1.**). Because of the geographic location, Puerto Rico is frequently affected by the Sahara dust transported from North Africa across the Atlantic Ocean through the Sahara Air Layer (SAL). One of the events that most affected the island was in June 2020, which was named Godzilla Dust event. Which affected atmospheric conditions, thus affecting atmospheric conditions. This study focuses on Puerto Rico as the area of interest for evaluating the effects of the June 2020 Saharan dust event on satellite imagery.

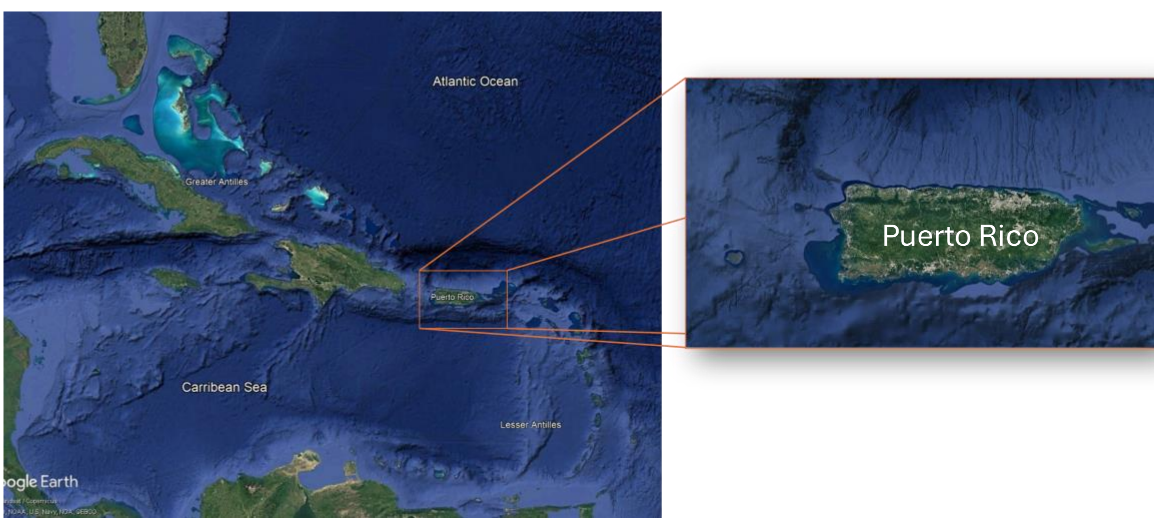

Figure 1.*Location of Puerto Rico within the Greater Antilles region of the Caribbean. The study area is centered at approximately 18.17° N, 66.42° W.*

2.2: Data Acquisition

The satellite images used in this study were acquired from Nasa Worldview. The imagery was derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Aqua satellite using the Corrected Reflectance (True Color) Version 6.1 product. The selected imagery covered Puerto Rico. Two images, acquired on June 20 and June 22, 2020 (

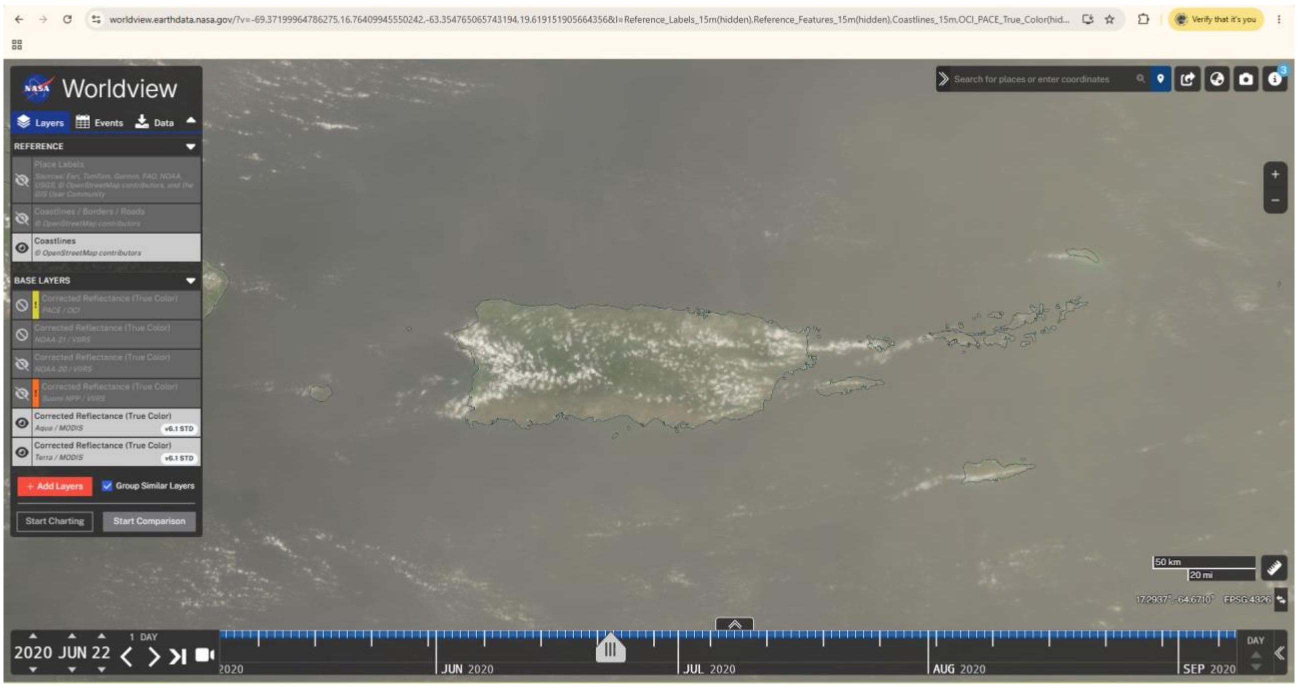

Figure 2) were selected based on visual estimation of the atmospheric conditions to represent periods before and during the June 2020 Saharan dust event, respectively.

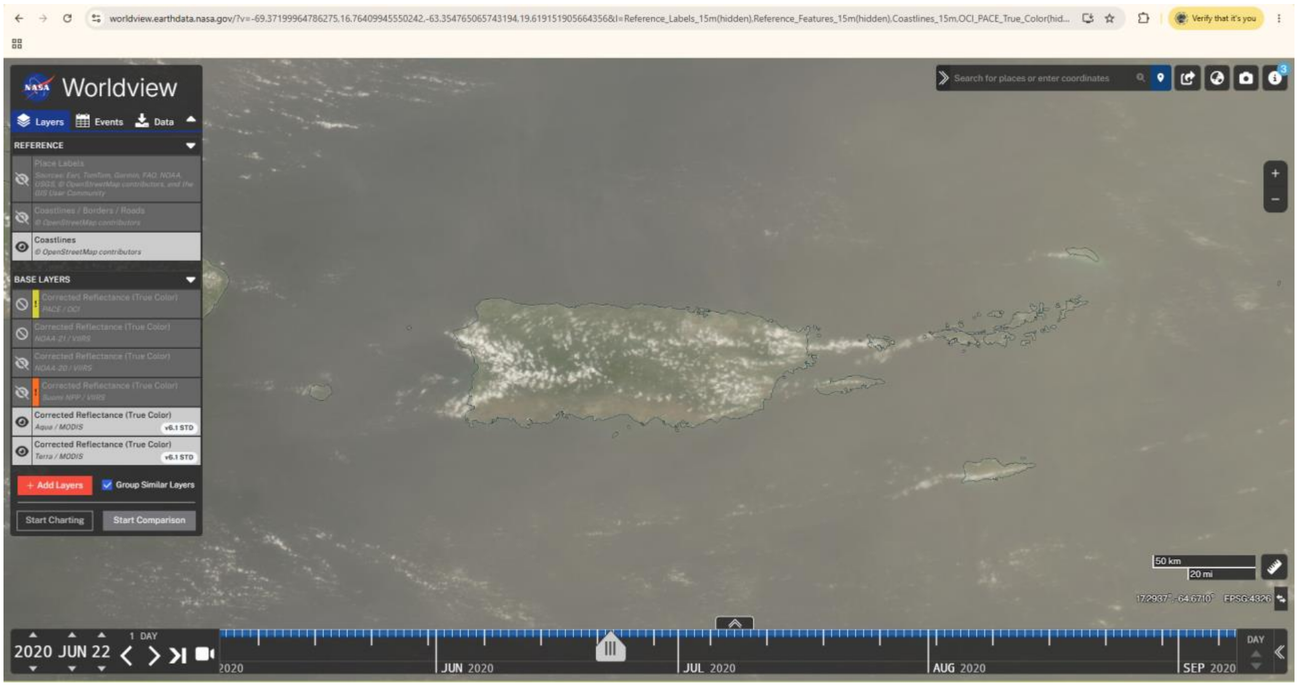

Figure 2.*NASA Worldview Aqua/MODIS image of Puerto Rico on June 22, 2020.*

2.3: Image Processing and Analysis

The acquired images were imported into ENVI 6.2 software. The image from June 20, 2020, was ready for processing, as it contained the geographic reference information. The image from June 22, 2020, did not. Therefore, image-to-image registration was performed using the image from June 20, 2020, as the reference dataset. To establish spatial correspondence, ground control points (GCPs) were selected from recognizable features present in both images to establish spatial correspondence using placemarks tool. Following the registration process, a warp transformation was applied to align the June 22, 2020, image with the reference image. Once both images were properly georeferenced (***Figure 3.****June 22, 2020, image after georeferencing and warp* *transformation in ENVI 6.2.*), they were prepared for visual interpretation and spectral analysis. Visual analysis was conducted using the red, green, and blue (RGB) channels of the true-color imagery to evaluate differences in atmospheric appearance between the two dates. In addition, pixel values from selected regions were extracted and compared between both images to assess variations in spectral response associated with atmospheric conditions (**Table 1**).

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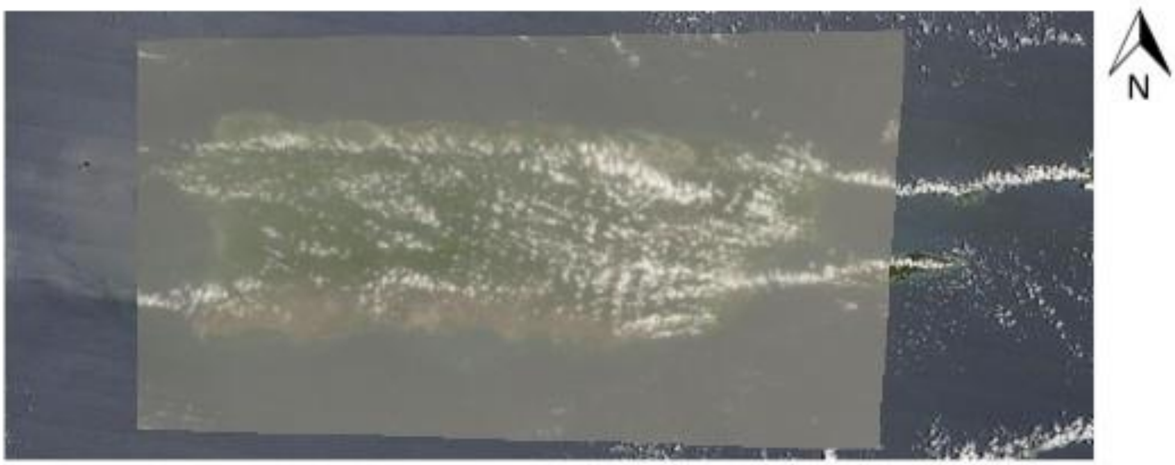

Figure 3.*June 22, 2020, image after georeferencing and warp transformation in ENVI 6.2.*

Point	Area	RGB (20-Jun-2020)	RGB (22-Jun-2020)
1	Atlantic Ocean	[91,95,107]	[111,112,107]
2	Caribbean Sea	[93,69,43]	[136,128,115]
3	South Coast of Puerto Rico	[118,98,74]	[137,130,114]
4	Bosque Estatal de Maricao	[36,54,28]	[118,123,103]

5	Northwest coast of Puerto Rico	[143,150,119]	[138,139,125]

Table 1.*Comparison of RGB pixel values between the June 20 and June 22, 2020 images.*

2.4: Image Classification

After performing image registration and geometric correction, visual interpretation of the imagery acquired on June 20 and June 22, 2020, was conducted. Both images were examined to identify visible differences associated with the Saharan dust event and to better understand the atmospheric conditions present on each date. Characteristics such as color, brightness, and image appearance were observed and compared between the two images. This initial analysis served as the basis for the subsequent steps of the study.

To further evaluate the observed differences, RGB pixel values were extracted from both images and compared. The red, green, and blue values were organized and summarized in **Table 1**. The comparison of these values allowed for the identification of spectral variations between the two image dates. This information was used to complement the visual interpretation of the imagery before performing the classification analysis.

After comparing the RGB values, representative areas within the image were selected for classification. The Region of Interest (ROI) Tool was used to delineate areas that exhibited similar visual and spectral characteristics. A total of seven classes were established: Ocean, Ocean and Dust, Ocean and High Dust, Vegetation, Vegetation and Dust, Dry Vegetation, and Clouds (**Figure 4**). These classes were used to represent the principal surface and atmospheric features observed throughout the study area.

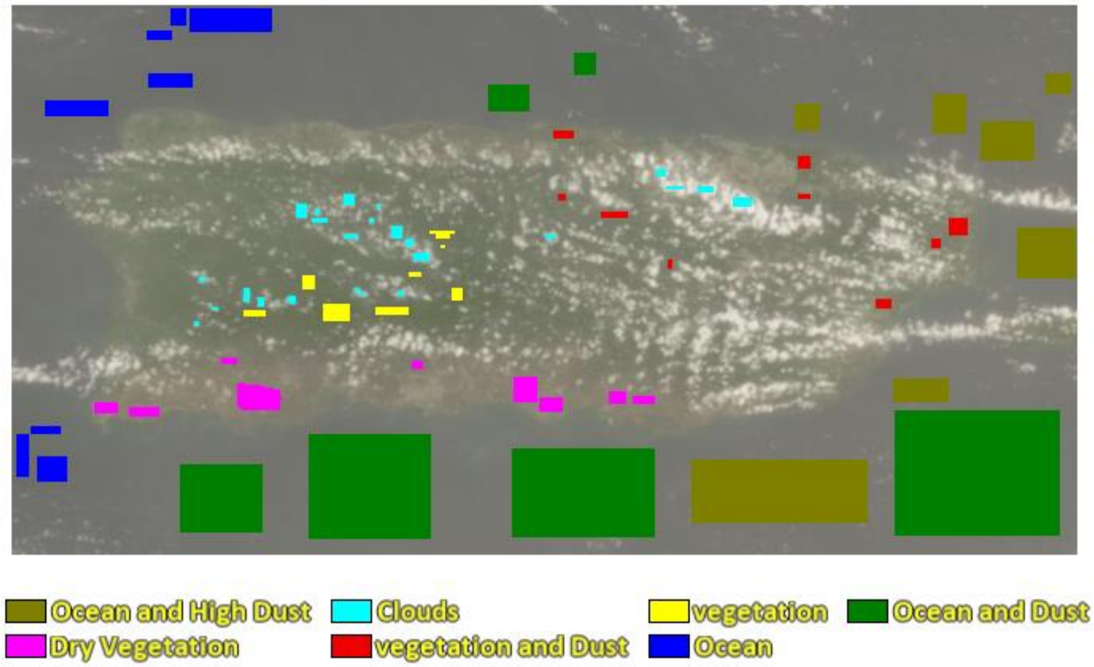

Figure 4. *ROIs selected for supervised image classification.*

The generated ROIs were used as training samples for supervised classification. Maximum Likelihood and Minimum Distance classification methods (**Figure 5**) were applied to the imagery using the selected training classes. Classification maps were generated for each method and used for comparison. In addition, unsupervised classification was performed using the IsoData and K-Means algorithms (**Figure 6**). For both methods, the imagery was divided into ten classes based on spectral similarity. The resulting classification maps were subsequently used for analysis and comparison.

III) Results

Visual Analysis of the Dust Event

A comparison of satellite imagery acquired during and before the June 2020 “Godzilla” Sahara dust event revealed noticeable differences in image quality and atmospheric conditions. Images collected during the dust intrusion exhibited reduced visibility, lower contrast, increased atmospheric haze, and washed-out colors. Surface features appeared less distinct due to the scattering and absorption of solar radiation by suspended dust particles in the atmosphere. In contrast, imagery acquired before the event showed improved visibility, greater contrast, and clearer definition of land surface features.

Spectral Response Analysis

The comparison of digital values obtained from selected image bands indicated changes in spectral response associated with the presence of Sahara dust. Atmospheric aerosols altered the amount of radiation reaching the satellite sensor, resulting in measurable differences between images acquired during and before the dust event. These variations suggest that Sahara dust significantly affects the spectral characteristics of remotely sensed data and should be considered when interpreting satellite imagery collected during major dust intrusions.

Supervised Classification Results

Supervised classification was performed using the Maximum Likelihood and Minimum Distance algorithms. Both methods successfully identified Sahara dust as a distinct class from other surface and atmospheric features. The Maximum Likelihood classifier produced the most consistent and realistic classification results, providing better separation between dust and surrounding classes. Training regions of interest (ROIs) allowed the algorithms to accurately recognize spectral patterns associated with airborne dust.

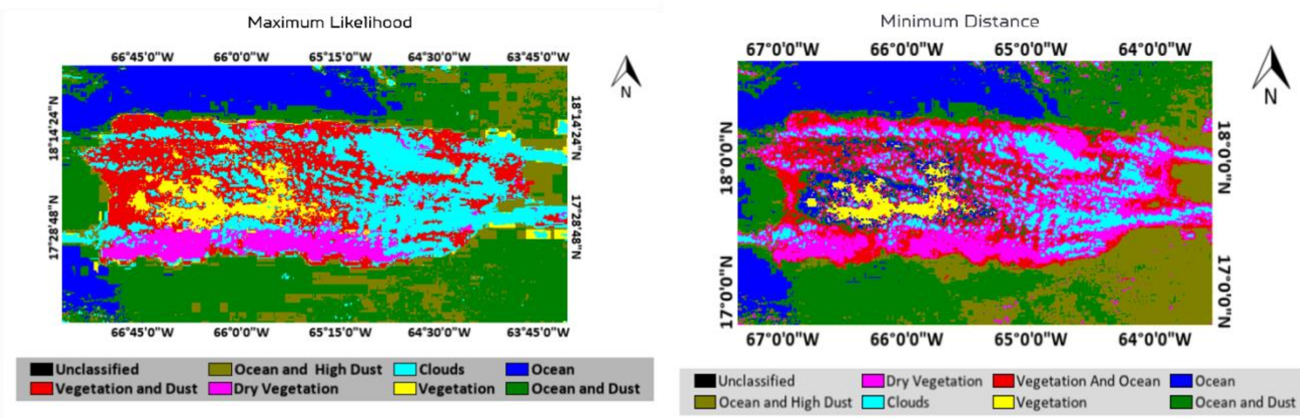

Figure 5.*Comparison of supervised classification results obtained using the Maximum Likelihood and Minimum Distance methods.*

Unsupervised Classification Results

Unsupervised classification was conducted using the IsoData and K-means algorithms with ten classes. Both methods successfully generated independent classes corresponding to areas affected by Sahara dust without requiring prior training data. The resulting classifications demonstrated that dust possesses unique spectral characteristics that can be distinguished automatically from other image features. Although some class variability was observed, both approaches effectively detected the spatial extent of the dust plume.

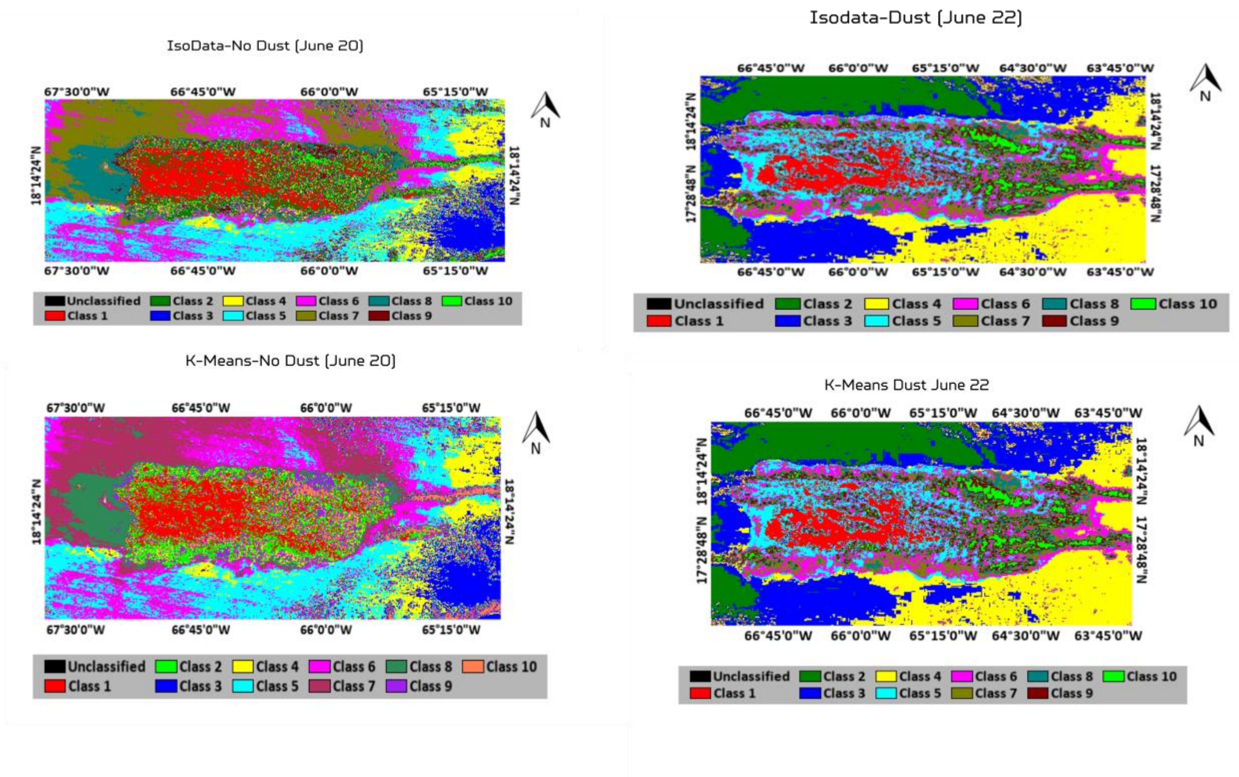

Figure 6. *Unsupervised classification results obtained using the IsoData and K-Means methods for the June 20 and June 22, 2020 images.*

IV) Discussion

The results demonstrate that the June 2020 “Godzilla” Sahara dust event had a significant influence on the spectral response and visual quality of the satellite imagery over Puerto Rico. The observed reduction in visibility, contrast, and image clarity is consistent with the known effects of atmospheric aerosols on electromagnetic radiation [3]. The successful identification of Sahara dust through both supervised and unsupervised classification methods indicates that dust events produce distinct spectral signatures that can be detected using remote sensing techniques. The ability of the IsoData and K-Means algorithms to isolate dust without prior training suggests that the spectral characteristics of the dust plume were sufficiently different from other land and atmospheric features present on the imagery [5]. Among the supervised methods, Maximum Likelihood provided the most reliable classification performance. This result is expected because the algorithm considers the statistical distribution of spectral values within each training class, allowing for more accurate class assignments compared to simpler distance-based methods [8]. The findings support previous studies that have documented the influence of Sahara dust on satellite observations throughout the Caribbean region. Similar research has reported reductions in imagery quality, changes in atmospheric optical properties, and successful confirmation that major dust outbreaks such as the 2020 "Godzilla" event can affect remotely sensed imagery and highlights the importance of accounting for atmospheric conditions when analyzing satellite data [3][4]. One limitation of this study was the inability to obtain ground-based PM10 and PM2.5 measurements for the study period. As a result, direct comparisons between satellite observations and air quality data could not be performed. Another limitation was the inability to access AOD data from the MODIS sensor due to paywalls. Future investigations should integrate atmospheric monitoring datasets with remote sensing observations in addition to analyzing multiple events in order to better understand the relationship between dust transport and air quality impacts in Puerto Rico.

V) Conclusion

The June 2020 Godzilla Sahara dust event had a measurable impact on the spectral characteristics and visual quality of satellite imagery over Puerto Rico. Comparison of images acquired during and before the event showed reduced visibility, lower contrast, and increased atmospheric haze associated with a high concentration of airborne dust particles. Image classification techniques proved effective for detecting and separating Sahara dust from other land and atmospheric features. Both supervised and unsupervised classification methods successfully identified dust as an independent class. However, the Maximum Likelihood classifier provided the most accurate and consistent result among the supervised approaches. The findings demonstrate that Sahara dust significantly influences the spectral response recorded by satellite sensors and can affect the interpretation of remotely sensed data. Consequently, remote sensing represents a valuable tool for monitoring dust transport events and evaluating their effects on satellite observations in the Caribbean region. A limitation of this study was the lack of publicly available PM10 and PM2.5 data for the selected study period, which prevented a direct comparison between satellite observations and ground-based air quality measurements. Future studies should incorporate air-quality datasets and additional dust events to further evaluate the relationship between atmospheric dust concentrations and satellite-derived observations.

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