# Mapping Urban Vegetation Changes Using PlanetScope Imagery and GIS: A Case Study of the 2024 Dubai Flood

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**Abstract**

In April 2024, unexpected heavy rainfall triggered one of the most severe flooding events in Dubai's recent history, causing widespread concern for urban infrastructure and green spaces. This study evaluates the flood's impact on urban vegetation in South Dubai using high-resolution PlanetScope satellite imagery and the Normalized Difference Vegetation Index (NDVI). Vegetation conditions before and after the flood (April 14 and April 18–19, 2024) were quantified and compared using NDVI analysis within QGIS to assess changes in vegetation health and coverage. Results indicate significant declines in vegetation health in areas dominated by intensive turf management, such as Damac Hills and Jumeirah Golf Estates, while eco-oriented and sustainably designed communities, including The Sustainable City, displayed stable or slightly improved NDVI values. NDVI difference mapping highlighted both vegetation losses and localized gains, revealing a highly heterogeneous impact across the urban landscape. The study demonstrates the utility of remote sensing and NDVI-based analysis as effective tools for monitoring vegetation response to extreme weather events and provides insights to support urban planning, green infrastructure design, and resilience strategies in rapidly expanding arid cities.

## 1. Introduction

Dubai has rapidly transformed into a global urban center, characterized by expansive residential neighborhoods, golf courses, and recreational areas integrated into its hyper-arid desert landscape. Vegetation within the city serves essential ecological, climatic, and social functions: it mitigates the urban heat island effect, enhances air quality by reducing particulate matter and carbon dioxide (Taha, 1997; Bowler et al., 2010), provides recreational and aesthetic amenities, and contributes to the overall livability and well-being of urban residents. Maintaining such green spaces in a desert environment requires continuous irrigation, advanced landscaping practices, and substantial infrastructure investment, particularly in terms of water management and soil preparation.

In April 2024, Dubai experienced an unprecedented rainfall event, recording 142 mm in less than 24 hours, the highest ever documented in the city (Royal Meteorological Society, 2024). The resulting floods inundated roads, disrupted transportation networks, and affected landscaped areas across the urban fabric. While extreme rainfall is rare in the Gulf region, climate projections indicate that the frequency and intensity of such events are likely to increase, posing new challenges for urban planning and ecosystem management (IPCC, 2023). Flooding can negatively impact vegetation through waterlogging, root suffocation, soil erosion, and nutrient leaching, although some species may temporarily benefit if soil drainage allows adequate water infiltration (Zhou et al., 2020).

The resilience of urban vegetation in arid cities depends on a combination of natural and anthropogenic factors.

Species selection, irrigation strategies, soil amendments, and landscape design all influence whether plants can recover rapidly or deteriorate after flooding. Communities that integrate water-sensitive urban design (WSUD) principles, such as efficient drainage, drought-tolerant species, and adaptive maintenance practices, tend to maintain higher vegetation health during extreme events (Brown et al., 2009; Klein et al., 2021). In contrast, turf-dominated developments with limited drainage are highly dependent on regular irrigation and are more susceptible to flood damage.

Remote sensing provides a reliable and scalable approach to assess vegetation responses to environmental disturbances. The normalized difference vegetation index (NDVI), introduced by Rouse et al. (1974), is widely used to monitor plant health, canopy greenness, and stress levels. NDVI has been successfully applied in post-flood studies to detect vegetation decline and recovery patterns (Atefi & Miura, 2022; Fensholt et al., 2012). PlanetScope imagery, with its daily revisit cycle and 3-m spatial resolution, allows fine-scale monitoring of urban vegetation dynamics. When integrated with GIS, NDVI enables spatially explicit mapping of vegetation health and stress, facilitating the identification of vulnerable areas and resilience patterns.

The objective of this study is to: (1) map vegetation before and after the April 2024 flood in South Dubai; (2) evaluate community-level variations in vegetation response; and (3) discuss implications for sustainable urban landscaping and resilience strategies in arid environments. By combining remote sensing and spatial analysis, this research provides practical insights for urban planners, landscape managers, and policymakers facing increasing climate extremes in desert cities.

## 2. Study Area

The study focuses on South Dubai, an area that includes a combination of residential neighborhoods, recreational spaces, and commercial zones, covering approximately 24 km². Residential areas include Green Community Village, DAMAC Hills, Arabian Ranches 2, and The Sustainable City, each characterized by different landscaping approaches and levels of investment in irrigation and drainage infrastructure. Recreational landscapes, such as Jumeirah Golf Estates and Dubai Sports City, feature large turf-dominated areas that are particularly vulnerable to flooding and waterlogging. Motor City represents the commercial and light industrial sector, where green spaces are smaller but still contribute to the urban fabric.

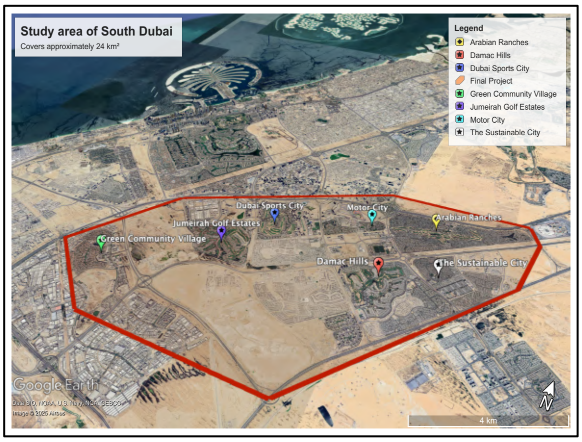


**Figure 1. Location of the study area and its primary land-use zones**

Dubai's climate is classified as hot desert. Average annual rainfall is about 100 mm, occurring in short, irregular storms, while summer temperatures often exceed 45°C. Natural vegetation is sparse, and most greenery relies on irrigation. The April 2024 rainfall far exceeded the city's drainage capacity, leading to widespread surface water accumulation. This rare climatic shock created an opportunity to evaluate how differently designed communities responded in terms of vegetation health.

## 3. Data and Methodology

### 3.1 Remote sensing data

PlanetScope multispectral imagery, with a spatial resolution of 3 m, was selected to capture vegetation conditions before and after the April 2024 flood. Two cloud-free images were obtained: one on 14 April 2024 (pre-flood) and another on 18 April 2024 (post-flood). The four available spectral bands (Blue, Green, Red, and Near-Infrared [NIR]) enabled the computation of vegetation indices sensitive to plant greenness and vigor.

### 3.2 NDVI computation

NDVI was calculated using the Red and NIR bands with the following formula:

$$NDVI=(NIR - Red) / (NIR + Red) \qquad (1)$$

The NDVI difference was computed as:

$$NDVI_{diff}= NDVI_{Apr18} - NDVI_{Apr14} \qquad (2)$$

This allowed the identification of areas where vegetation declined, remained stable, or improved after the flood. A classification scheme was applied: values below 0 indicated non-vegetated surfaces such as sand, rocks, or built-up areas; 0.01–0.30 corresponded to sparse or stressed vegetation; 0.31–0.60 represented moderately dense vegetation; and 0.61–1.0 denoted healthy, highly dense vegetation. The resultant NDVI data were further used for calculating the NDVI difference between pre- and post-rainfall dates.

### 3.3 GIS processing

All image preprocessing and analysis were performed in QGIS. Community boundaries were delineated using municipal GIS data and manual digitization. NDVI rasters for both dates were produced, followed by the computation of an NDVI difference layer. Color-coded maps were generated to visually highlight zones of vegetation loss (shades of brown) and zones of vegetation gain (shades of green). To quantify the changes, zonal statistics were calculated for each community, including mean, minimum, maximum, and standard deviation of NDVI values.

### 3.4 Supporting analysis

Δ NDVI[1] histogram emphasized the proportion of pixels that showed positive or negative changes. These statistical and

[1] NDVI Difference

visual tools allowed comparison across communities and identification of the most affected landscapes.

## 4. Results

The NDVI analysis revealed varied vegetation responses to the April 2024 flood across South Dubai. The average NDVI value decreased from 0.26 before the flood to 0.20 after the flood, indicating a general decline in vegetation health across the study area. NDVI values before the flood ranged from –0.21 to 0.61, and after the flood from –0.27 to 0.56. This shift suggests that many vegetated surfaces experienced water stress, with fewer pixels remaining in the moderately dense and highly dense categories.

Based on the classification scheme (*Table 1*), values below 0 represented non-vegetated areas; values between 0.01 and 0.30 indicated slightly dense or stressed vegetation; values from 0.31 to 0.60 corresponded to moderately dense vegetation; and values between 0.61 and 1.0 reflected healthy and highly dense vegetation.

| NDVI Value | Vegetation Class |
|---|---|
| -1.00 – 0.00 | No vegetation (ND) |
| 0.01 – 0.30 | Slightly dense (SD) |
| 0.31 – 0.60 | Moderately dense (MD) |
| 0.61 – 1.00 | Highly dense (HD) |

**Table 1. NDVI Classification Scheme**

Community-level analysis showed clear differences, in DAMAC Hills and Jumeirah Golf Estates, dominated by golf courses and expansive turf, NDVI values dropped sharply by as much as –0.30. These reductions indicate severe stress, most likely due to waterlogging, poor drainage, and physical damage to intensively managed lawns. Arabian Ranches 2 showed more moderate declines (–0.10 to –0.20), particularly in smaller green patches and roadside vegetation, where water may have stagnated temporarily.

In contrast, The Sustainable City displayed resilience, with localized increases in NDVI reaching +0.15, demonstrating that its stormwater and landscape systems allowed plants to benefit from enhanced soil moisture. Green Community Village also recorded slight improvements near water features, bioswales, and shaded areas, highlighting the role of integrated design in mitigating damage.

*Figure 2* represents NDVI maps generated from QGIS for the pre-flood (April 14) and post-flood (April 18–19) periods. A visual comparison clearly highlights a widespread reduction in vegetation intensity across many neighborhoods, with the most pronounced decline observed in turf-dominated areas such as Damac Hills and Jumeirah

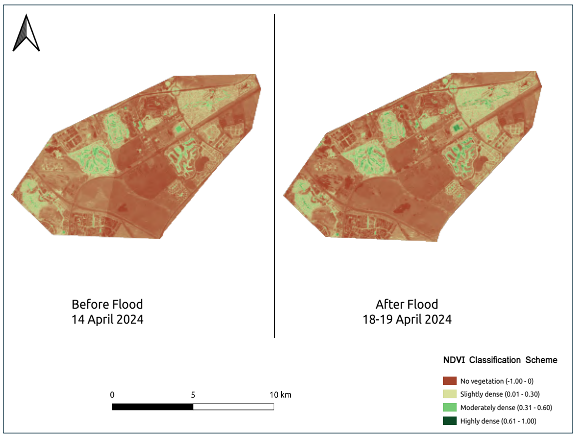


**Figure 2. QGIS generated maps of vegetation change before and after the flood**

Golf Estates. The maps reveal not only areas of vegetation loss but also localized patches where NDVI values remained stable or slightly increased, particularly in eco-oriented developments like The Sustainable City and Green Community Village. This contrast illustrates the heterogeneous impact of flooding on urban vegetation and underscores the influence of landscape design and water management on plant resilience.

*Figure 3* shows the ΔNDVI map, where vegetation loss is displayed in brownish-red and vegetation gain in dark green. The map clearly identifies localized decline in DAMAC Hills and Jumeirah Golf Estates, contrasted with small patches of improvement in The Sustainable City and Green Community Village.

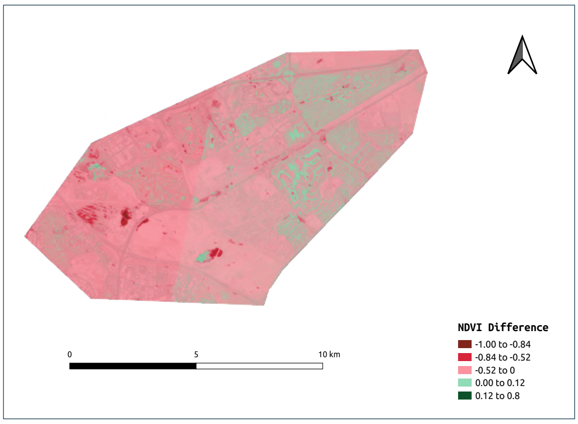


**Figure 3. QGIS generated map of NDVI difference**

The statistical distribution of NDVI values further supports these spatial patterns.

*Figure 4* shows the histogram for the pre-flood image, with a concentration of values around 0.25–0.30, reflecting healthy to moderately dense vegetation.

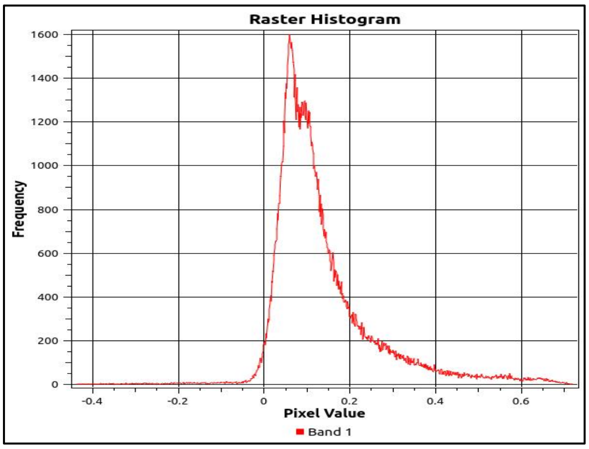


**Figure 4. Pre-flood histogram generated by QGIS**

*Figure 5* illustrates the post-flood histogram, where the curve shifts leftward, indicating a broad reduction in vegetation health. This shift reflects that a substantial portion of the study area experienced a decline from moderately dense or healthy vegetation to sparse or stressed conditions.

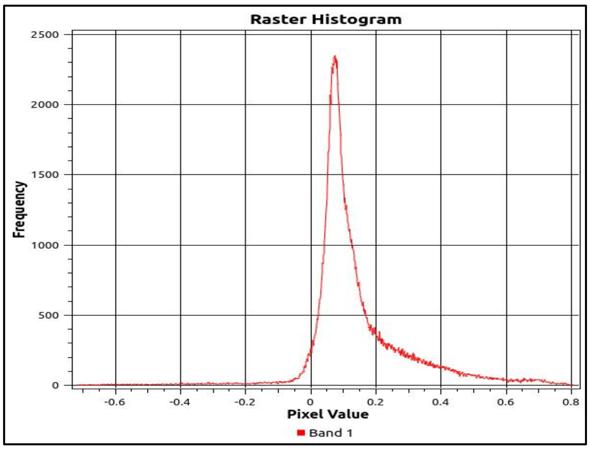


**Figure 5. Post-flood histogram generated by QGIS**

Finally, *Figure 6* presents the NDVI difference histogram, which illustrates the magnitude and spatial variability of vegetation change across the study area. The distribution indicates that while the majority of pixels experienced a decline in NDVI values, reflecting widespread stress and partial loss of vegetation, a subset of areas showed slight increases. These localized gains suggest that some vegetation patches were able to take advantage of additional soil moisture, possibly due to better drainage, microtopography, or landscape design features that enhanced resilience.

Overall, the histogram underscores the heterogeneous nature of the flood's impact, highlighting that vegetation response in urban arid environments is highly site-specific and influenced by both natural and anthropogenic factors..

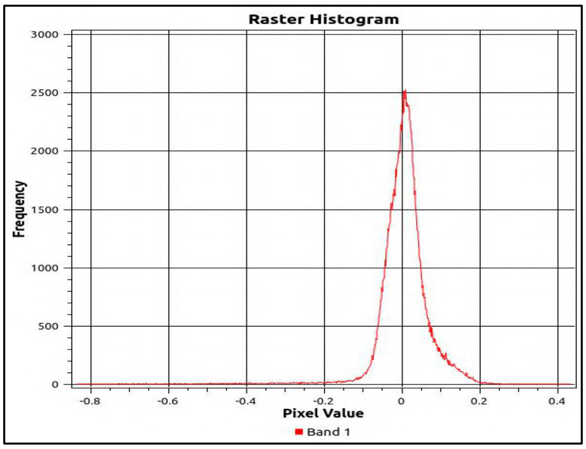


**Figure 6. NDVI difference histogram generated by QGIS**

## 6. Discussion

The April 2024 flood in South Dubai revealed significant variability in vegetation responses across different urban communities, underscoring the critical role of landscape design and water management in enhancing ecological resilience in arid environments. Our NDVI analysis demonstrated that communities with turf-dominated landscapes, such as Damac Hills and Jumeirah Golf Estates, experienced substantial declines in vegetation health, with NDVI values dropping by up to 0.30. This decline is consistent with findings from studies in arid regions, where intensive turf areas are highly susceptible to waterlogging and root suffocation during extreme rainfall events (Sims & Colloff, 2012).

In contrast, eco-oriented developments like The Sustainable City exhibited resilience, with localized NDVI increases of up to 0.15. This suggests that integrated landscape designs, which incorporate sustainable water management practices, can mitigate the adverse effects of flooding on vegetation health. Similar outcomes have been reported in other arid regions, where communities employing water-sensitive urban design principles demonstrated improved vegetation recovery post-flood (Klein et al., 2021)

The ΔNDVI maps further emphasized the heterogeneous impact of the flood, revealing both losses and gains in vegetation across the urban landscape. This patchiness underscores the necessity for targeted resilience strategies that consider local landscape characteristics and hydrological conditions. Studies have shown that vegetation responses to flooding can vary significantly within small spatial scales, highlighting the importance of fine-resolution monitoring to capture these variations (Steyer et al., 2013).

While NDVI proved effective in mapping the spatial extent and magnitude of vegetation change, it has some limitations; NDVI cannot always differentiate between short-term greenness caused by soil moisture and actual vegetation growth, potentially leading to overestimation of recovery in some areas.

To address this, future research should include field validation and more frequent satellite observations to track long-term recovery and accurately assess vegetation health (Zhang et al., 2021).

In conclusion, integrating remote sensing tools like NDVI with GIS provides valuable insights into vegetation responses to extreme weather events in urban arid environments. These insights can inform urban planning and landscape management strategies aimed at enhancing ecological resilience and ensuring the sustainability of green spaces in the face of climate change.

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