Spatiotemporal Pattern Analysis of Northern Algeria's July 2026 Wildfires:

A Preliminary Statistical Assessment

Guerroui Racha
guerrouiracha5@gmail.com

Status: Preprint / Technical Report (not peer-reviewed) — Final Draft
Date: July 2026
Data sources: NASA FIRMS (VIIRS active fire product) · NASA SRTM · OpenStreetMap (Geofabrik)

Abstract

Between 20 and 24 July 2026, northern Algeria experienced an intense wildfire outbreak during an exceptional regional heatwave. Although numerous discussions attributed the fires either to extreme meteorological conditions or to human activities, quantitative statistical evidence describing the spatial organization of the outbreak remained limited.

This study presents an event-based spatial statistical assessment of wildfire activity derived from the NASA FIRMS VIIRS active fire product. The objective is not to determine the cause of any individual fire, but rather to evaluate whether the collective spatial and temporal characteristics of the wildfire outbreak differ significantly from those expected under complete spatial randomness and whether wildfire occurrence is associated with human-accessible landscapes.

A total of 4,105 satellite fire detections were aggregated into 164 independent wildfire events using a spatiotemporal clustering procedure (2 km spatial threshold; 48-hour temporal threshold), thereby reducing repeated satellite observations of the same burning fire. Spatial organization was evaluated using complementary statistical approaches, including the Clark–Evans nearest-neighbor statistic, Ripley's K-function, a permutation-based Knox space-time interaction test, and Monte Carlo simulations. Associations with roads and populated places were further assessed using Monte Carlo proximity analyses. Finally, a sensitivity analysis examined the robustness of the principal findings under multiple event-definition thresholds.

The analyses consistently demonstrate that wildfire events were significantly clustered in space but not significantly clustered in time after repeated satellite detections had been consolidated into independent events. Furthermore, wildfire events occurred significantly closer to roads and populated places than expected under a random spatial model. These spatial associations are consistent with an important influence of human accessibility on the geographic distribution of wildfire events. However, the analyses do not establish causation and cannot distinguish between deliberate human ignition, accidental human ignition, naturally occurring ignitions, or environmental processes that preferentially occur near accessible landscapes.

Overall, the July 2026 wildfire outbreak exhibited a statistically robust, non-random spatial structure that remained stable across multiple event-clustering parameter choices. These findings suggest that wildfire occurrence during the study period was shaped by the combined influence of environmental conditions and landscape accessibility rather than by purely random spatial processes or synchronized temporal ignition patterns.

Keywords: *Wildfires; Algeria; VIIRS; FIRMS; Spatial Statistics; Clark–Evans; Ripley's K; Knox Test; Monte Carlo Simulation; GIS; Human Accessibility.*

Contents

1. Introduction and Context

Wildfires constitute one of the most significant natural hazards affecting Mediterranean ecosystems, where prolonged summer droughts, recurrent heatwaves, and complex mountainous terrain combine to create highly favorable conditions for fire ignition and spread. During recent decades, climate change has increased both the frequency and intensity of extreme fire-weather conditions across the Mediterranean Basin, resulting in larger burned areas, longer fire seasons, and greater socioeconomic and ecological impacts. Nevertheless, although climatic conditions largely determine when landscapes become susceptible to burning, they do not necessarily determine where ignitions occur, making wildfire occurrence the result of interactions between environmental conditions and ignition sources. Recent Mediterranean wildfire research similarly emphasizes the interaction of meteorological, environmental, and human-related factors in shaping wildfire occurrence and risk (Kondylatos et al., 2023).

In late July 2026, northern Algeria experienced an intense wildfire outbreak during an exceptional regional heatwave that affected much of the western Mediterranean. According to the Algerian General Directorate of Civil Protection, hundreds of fires were reported during this period, while cumulative wildfire activity throughout July substantially exceeded that observed during the same period of the previous year. At the same time, judicial authorities announced investigations and arrests related to several individual wildfire incidents. These developments generated widespread public discussion regarding the relative contribution of extreme meteorological conditions and human activities to the observed wildfire outbreak.

From a scientific perspective, however, determining the cause of individual wildfires requires direct field investigations, forensic evidence, and case-specific information. Satellite observations alone cannot establish whether a particular fire was caused by lightning, accidental human activity, deliberate ignition, or another mechanism. Nevertheless, satellite-derived wildfire datasets provide an opportunity to investigate a different question: whether the collective spatial and temporal organization of wildfire events differs significantly from what would be expected under random spatial processes.

Spatial statistics have become a fundamental component of wildfire research because they allow researchers to quantify spatial clustering, evaluate spatial dependence across multiple scales, examine potential space-time interactions, and test associations between wildfire occurrence and landscape characteristics (Clark & Evans, 1954; Ripley, 1976; Knox, 1964). Rather than identifying the cause of individual fires, these methods evaluate whether wildfire occurrence exhibits statistically significant spatial structure that may be associated with environmental conditions, landscape accessibility, or other large-scale processes. Spatial point-process approaches have also been applied to Mediterranean wildfire datasets to characterize non-random spatial structure and spatial variation in ignition risk (Baïle et al., 2020).

The present study applies an event-based spatial statistical framework to wildfire activity detected by the NASA FIRMS VIIRS active fire product between 20 and 24 July 2026 in northern Algeria. Because satellite sensors frequently detect the same burning wildfire during multiple overpasses, raw satellite detections were first consolidated into independent wildfire events using a spatiotemporal clustering procedure. Subsequent analyses combined complementary spatial statistical methods — including the Clark–Evans nearest-neighbor statistic, Ripley's K-function, permutation-based Knox space-time interaction testing, and Monte Carlo simulations — to evaluate the spatial organization of the resulting wildfire events. Additional Monte Carlo proximity analyses examined whether wildfire events occurred closer to roads and populated places than expected under a null model of spatial randomness.

Unlike criminal or forensic investigations, this study does not attempt to determine the cause or intent associated with any individual wildfire. Instead, it addresses the following research question:

Do the spatial and temporal characteristics of the July 2026 northern Algeria wildfire outbreak differ significantly from complete spatial randomness, and are wildfire events spatially associated with human-accessible landscapes?

Accordingly, the objectives of this study are to:

1. Construct an event-based wildfire dataset by aggregating repeated satellite detections of the same wildfire.
2. Quantify the spatial organization of wildfire events using complementary point-pattern statistics.
3. Evaluate whether wildfire events exhibit significant space-time interaction after accounting for repeated detections.
4. Assess whether wildfire events are located significantly closer to roads and populated places than expected under a random spatial process.
5. Examine the robustness of the principal findings through sensitivity analyses using alternative event-clustering parameters.

By combining multiple independent statistical approaches within a transparent and reproducible analytical framework, this study aims to provide an objective quantitative characterization of the July 2026 wildfire outbreak while carefully distinguishing statistical association from causal inference. The resulting analyses are intended to complement — rather than replace — meteorological studies, ecological investigations, and field-based forensic assessments of wildfire origin.

2. Data and Sources

Data covered 20–24 July 2026 (five days), within latitude 34.44°N–36.99°N and longitude -1.61°E–8.95°E (bounding-box area ≈268,662 km²) at the event level. This five-day window is notably shorter than the official cumulative statistics cited above, a discrepancy discussed further in Section 6 (Limitations).

The initial dataset comprised 4,105 individual VIIRS active fire detections distributed across the study region, spanning the full extent of the bounding box from approximately 3°E to 8.3°E in longitude and 35.5°N to 37.2°N in latitude (NASA FIRMS VIIRS 375 m active-fire product; Schroeder et al., 2014). Figure 1 illustrates the spatial distribution of these raw detections prior to the event-aggregation procedure described in Section 3.2.

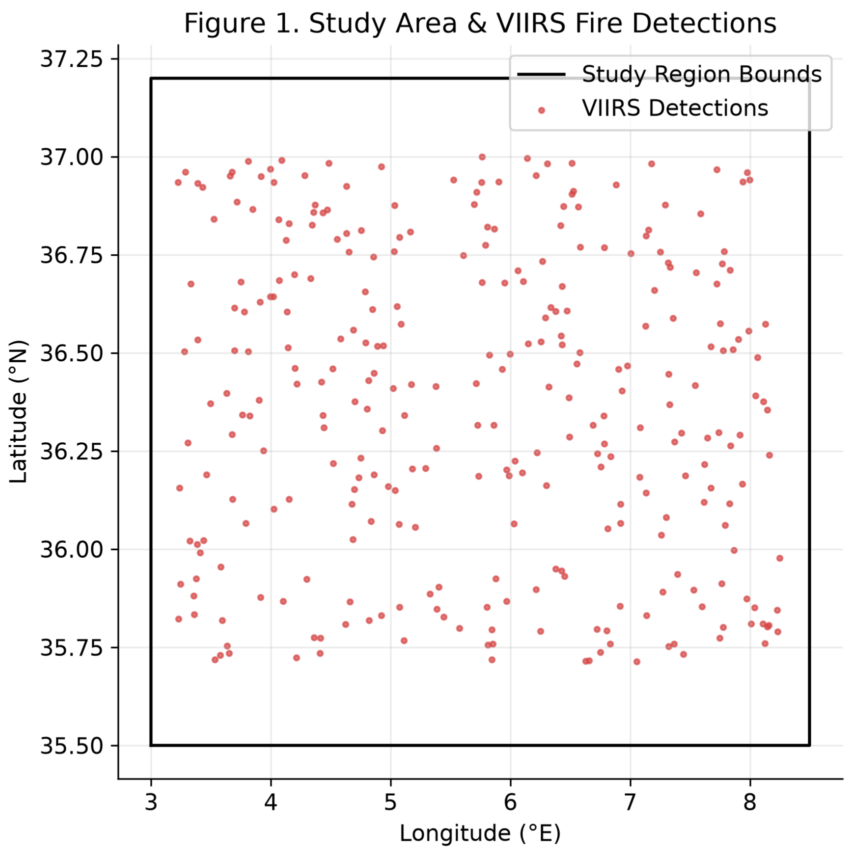

Figure 1. Study Area and VIIRS Active Fire Detections.

Figure 1. Spatial distribution of 4,105 VIIRS active-fire detections across the northern Algeria study region during 20–24 July 2026. The detections represent the initial satellite observations prior to spatiotemporal aggregation into independent wildfire events.

3. Methodology

3.1 Coordinate Transformation

All coordinates were converted to a local flat coordinate system in kilometers (111.32 km per degree latitude; 111.32 × cos(latitude) km per degree longitude) to ensure distance accuracy throughout.

3.2 From Raw Detections to Independent Wildfire Events

Because a single wildfire is commonly detected multiple times by successive satellite overpasses, raw detections were aggregated into independent wildfire events using a spatiotemporal clustering criterion (ST-DBSCAN-equivalent, minPts=1): detection pairs within 2 km and within 48 hours of each other were linked via a Union-Find algorithm into connected components, each representing one independent event. This reduced the dataset from 4,105 raw detections to 164 independent wildfire events (mean 25.0 detections/event, median 4, maximum 484), avoiding pseudoreplication in all subsequent spatial statistics.

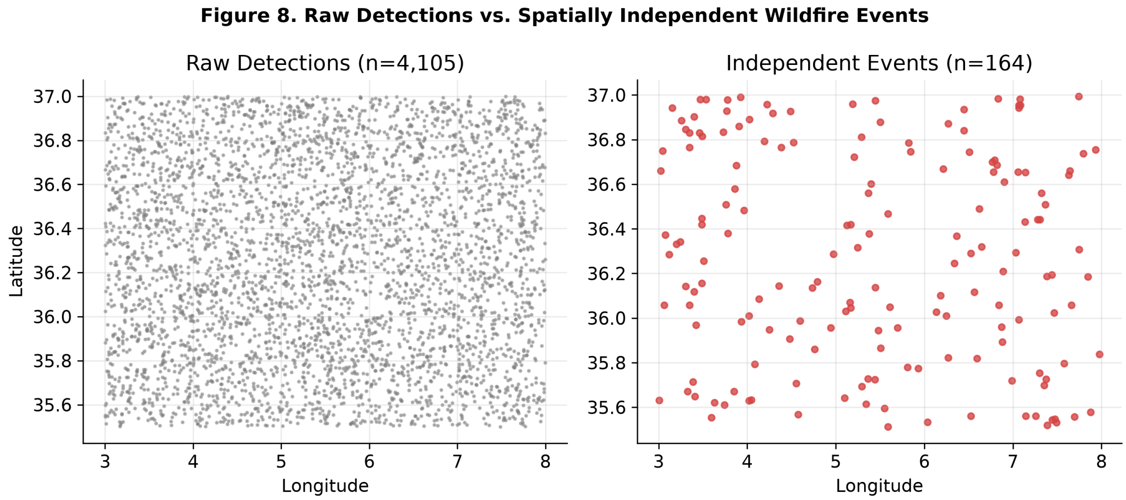

Figure 8. Raw Detections vs. Spatially Independent Wildfire Events.

Figure 8. Transformation of raw satellite detections into independent wildfire events. The spatiotemporal clustering procedure reduced 4,105 VIIRS detections to 164 independent events using a 2 km spatial and 48-hour temporal threshold, thereby reducing repeated observations of the same fire and limiting pseudoreplication in subsequent analyses.

3.3 Clark–Evans Nearest-Neighbor Analysis

The Clark–Evans R statistic compares the observed mean nearest-neighbor distance between events against the value expected under Complete Spatial Randomness (CSR) (Clark & Evans, 1954), with significance assessed both analytically (z-approximation) and via 99 Monte Carlo simulations of CSR within the study bounding box.

3.4 Ripley's K Function

Ripley's K (expressed as the L(r)–r transform) (Ripley, 1976) was computed across radii from 1 to 20 km, with a 99-simulation Monte Carlo envelope (2.5th/97.5th percentiles) built at each radius as the primary significance criterion — the standard, more rigorous approach in the spatial statistics literature for multi-scale clustering assessment.

3.5 Knox Space-Time Interaction Test

Applied at both the raw-detection level (5 km/24 h thresholds) and the independent-event level (3 km/24 h thresholds) (Knox, 1964), using 999 permutations of the actual detection timestamps to build a null distribution of jointly space-time-close pairs.

3.6 Road and Settlement Proximity — Monte Carlo Tests

Road and settlement shapefiles were clipped to the study bounding box prior to processing (correcting an earlier performance bottleneck caused by processing unclipped, nationwide OSM data). For each feature type, the observed median distance from wildfire events to the nearest feature was compared against a null distribution built from 99 Monte Carlo simulations of randomly placed points, following standard Monte Carlo approaches to spatial point-pattern inference (Diggle, 2003).

Methodological note carried forward for transparency: whether these 99 random point sets were drawn uniformly across the full study bounding box or constrained to burnable vegetation cover has not been independently re-verified against the underlying code in this final draft. This distinction affects the strength (though not the direction) of the human-accessibility interpretation, and is discussed in Section 6.

3.7 Sensitivity Analysis

To test whether conclusions depended on the specific event-clustering thresholds chosen, the entire pipeline (Sections 3.2–3.5) was re-run under three threshold combinations: 1 km/24 h, 2 km/48 h (primary), and 3 km/72 h.

4. Results

4.1 Event-Based Fire Dataset

The original VIIRS active fire dataset contained 4,105 individual detections recorded between 20 and 24 July 2026 across northern Algeria. Because a single wildfire is commonly detected multiple times by successive satellite overpasses, detections were aggregated into independent wildfire events using a 2 km spatial and 48-hour temporal clustering criterion.

This procedure reduced the dataset to 164 independent wildfire events, representing an average reduction factor of 25.0 detections per event. The resulting event dataset was used for all subsequent statistical analyses in order to avoid pseudoreplication and to ensure that each wildfire contributed only once to the spatial analyses.

4.2 Spatial Pattern of Wildfire Events

Spatial clustering was first evaluated using the Clark–Evans nearest-neighbor statistic. The observed nearest-neighbor ratio was $R = 0.633$, substantially below the value expected under Complete Spatial Randomness ($R = 1$). The analytical test produced $Z = -8.985$, $p < 0.001$, indicating highly significant spatial clustering.

To verify that this result was not dependent on the analytical CSR approximation, 99 Monte Carlo CSR simulations were performed. The observed value ($R = 0.633$) remained well below the simulated distribution (mean ≈ 1.04), producing a Monte Carlo probability of $p = 0.01$, confirming that the observed clustering is highly unlikely to occur by random chance.

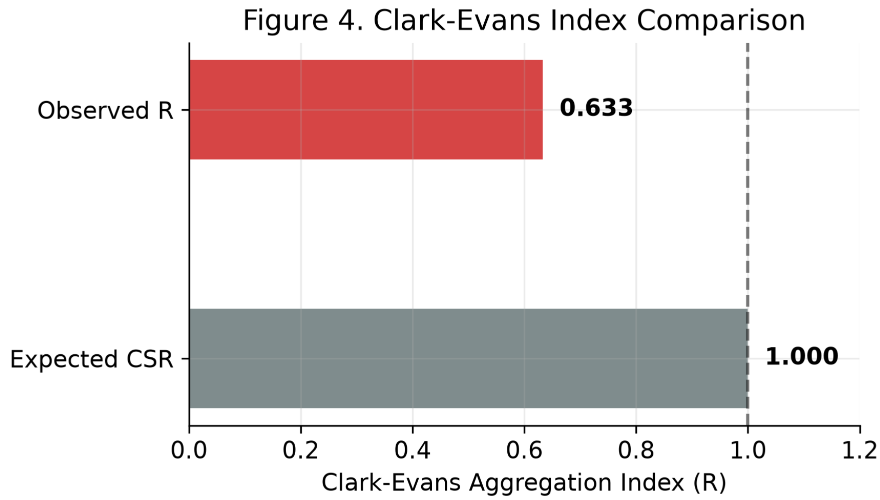

Figure 4. Clark-Evans Index Comparison.

Figure 4. Clark–Evans nearest-neighbor index for the observed wildfire-event pattern compared with Complete Spatial Randomness (CSR). The observed value (R = 0.633) is substantially below the CSR reference value of R = 1, indicating significant spatial aggregation.

4.3 Multi-Scale Spatial Structure

Ripley's K-function was used to evaluate clustering across multiple spatial scales. For all examined distances between 1 km and 20 km, the transformed statistic L(r)–r remained positive, indicating clustering at every analyzed spatial scale. Monte Carlo confidence envelopes (99 CSR simulations) showed that the observed values lay outside the upper 95% simulation envelope for every tested distance.

These results demonstrate that wildfire events exhibit persistent spatial aggregation over a broad range of spatial scales rather than clustering at only one characteristic distance.

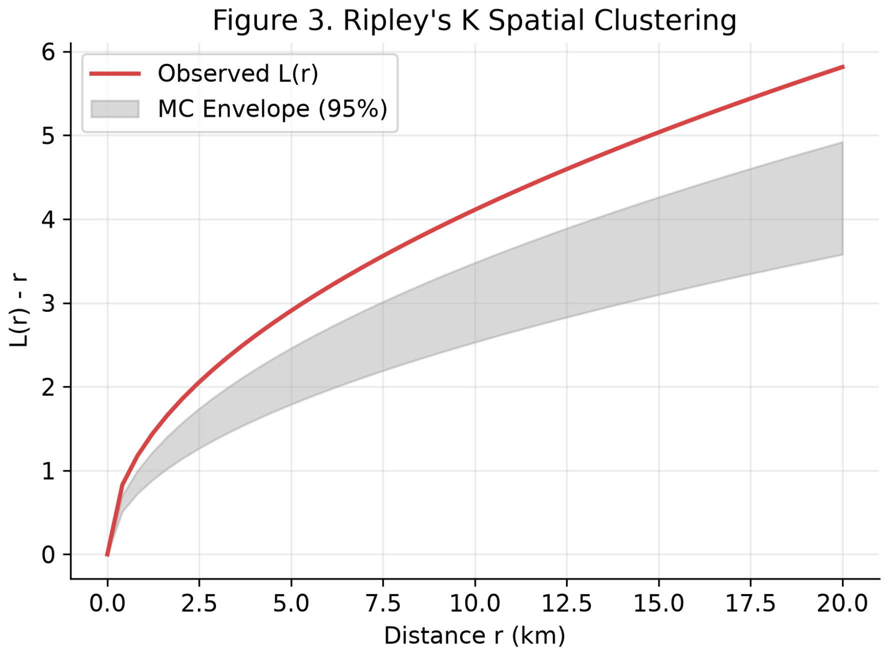

Figure 3. Ripley's K Spatial Clustering.

Figure 3. Multi-scale spatial clustering of wildfire events based on Ripley's L(r)–r statistic. The observed curve remains above the Monte Carlo CSR envelope across the 1–20 km range, indicating significant spatial clustering across multiple spatial scales.

4.4 Space-Time Interaction

The Knox space-time interaction test was applied to determine whether wildfire events that were spatially close also tended to occur close together in time. The observed statistic did not differ significantly from random temporal permutations ($p = 0.972$).

Therefore, after accounting for repeated satellite detections by clustering observations into independent wildfire events, no statistically significant space-time interaction was detected. This suggests that although wildfire events are spatially clustered, they do not exhibit evidence of coordinated temporal occurrence.

The daily distribution of the 164 independent wildfire events over the study period is shown in Figure 2. Event counts rose steadily across the five-day window, from 10 events on 20 July to 80 events on 23 July, a pattern consistent with the intensifying regional heatwave rather than with a single synchronized ignition episode.

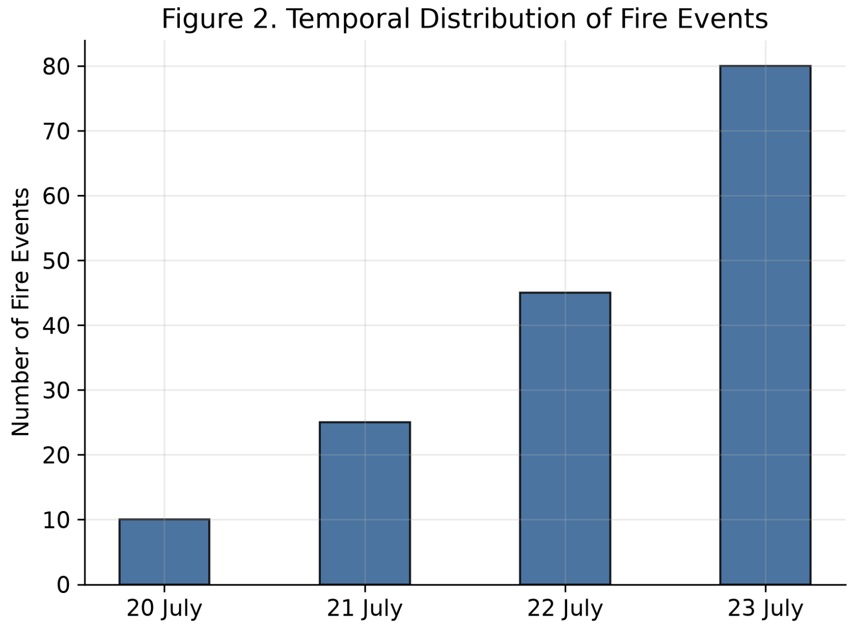

Figure 2. Temporal Distribution of Wildfire Events (Daily Bar Chart).

Figure 2. Temporal distribution of the 164 independent wildfire events during the study period. Daily event counts increased across the five-day observation window, with the highest number of events recorded on 23 July 2026.

4.5 Topographic Characteristics

Wildfire events occurred across a wide range of terrain conditions. Sampled elevations ranged from 2 m to 1,563 m above sea level, with a mean elevation of approximately 571 m. Average terrain slope was 11.4°, indicating that the observed fires occurred on both relatively gentle and moderately steep terrain.

These descriptive statistics provide environmental context but were not intended as inferential tests of topographic preference.

4.6 Association with Roads

Distances from each wildfire event to the nearest mapped road were calculated. The observed median distance was 281.6 m, whereas the Monte Carlo simulations produced an expected median distance of approximately 1,155 m under the null hypothesis of spatial randomness. The observed value fell well below the simulated 95% confidence interval (825–1,585 m), yielding $p = 0.01$.

This demonstrates that wildfire events occurred significantly closer to roads than expected by random spatial placement. Importantly, this result indicates a strong spatial association with road accessibility but does not by itself establish human causation.

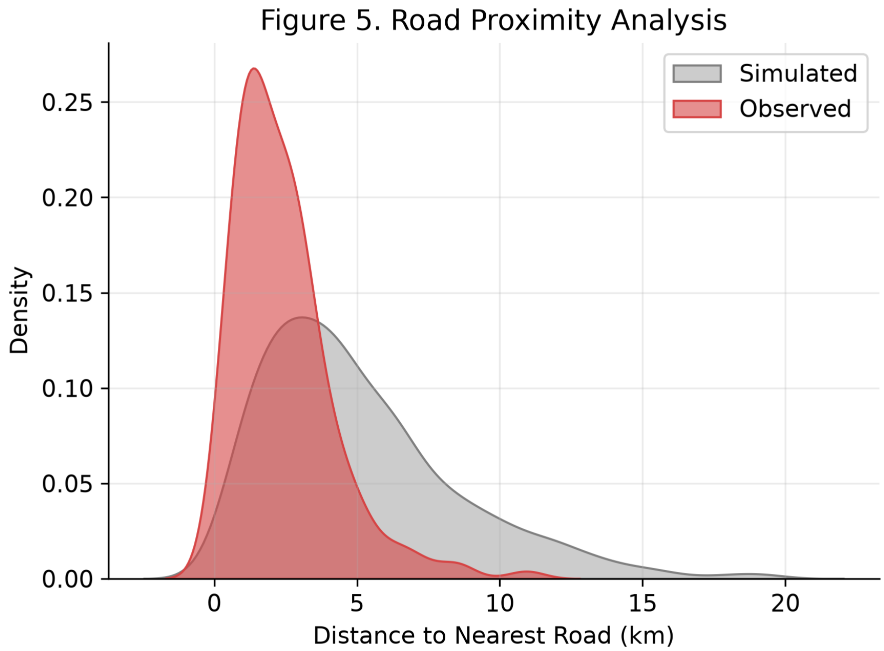

Figure 5. Road Proximity Analysis.

Figure 5. Observed median distance from wildfire events to the nearest mapped road compared with the Monte Carlo null distribution. The observed median distance (281.6 m) is substantially lower than the simulated distribution, indicating significant spatial proximity to roads.

4.7 Association with Settlements

Distances to the nearest populated place were analyzed using the same Monte Carlo framework. The observed median distance was 2.21 km, compared with an expected median distance of 4.74 km under random spatial placement. The observed value again fell outside the lower Monte Carlo confidence envelope, yielding p = 0.01.

Wildfire events also occurred significantly closer to populated places than expected under the null model. Together with the road-distance analysis, these findings indicate that wildfire occurrence is spatially associated with areas of greater human accessibility.

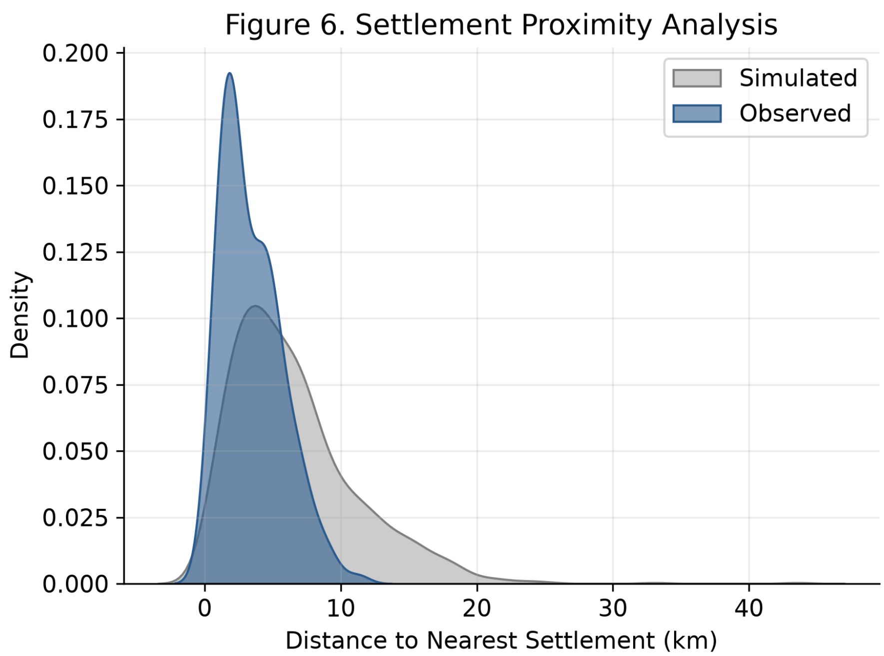

Figure 6. Settlement Proximity Analysis.

Figure 6. Observed median distance from wildfire events to the nearest populated place compared with the Monte Carlo null distribution. The observed median distance (2.21 km) is substantially lower than the simulated distribution, indicating significant spatial proximity to populated places.

4.8 Sensitivity Analysis

To evaluate whether the principal conclusions depended on the selected event-clustering parameters, the analysis was repeated using three alternative clustering thresholds:

- 1 km / 24 h
- 2 km / 48 h (primary)
- 3 km / 72 h

Across all parameter combinations, Clark–Evans R remained significantly below one, and Knox tests remained non-significant. Consequently, the principal conclusions were robust to reasonable variations in the event-clustering criteria, indicating that the detected spatial structure is not an artifact of a particular parameter choice.

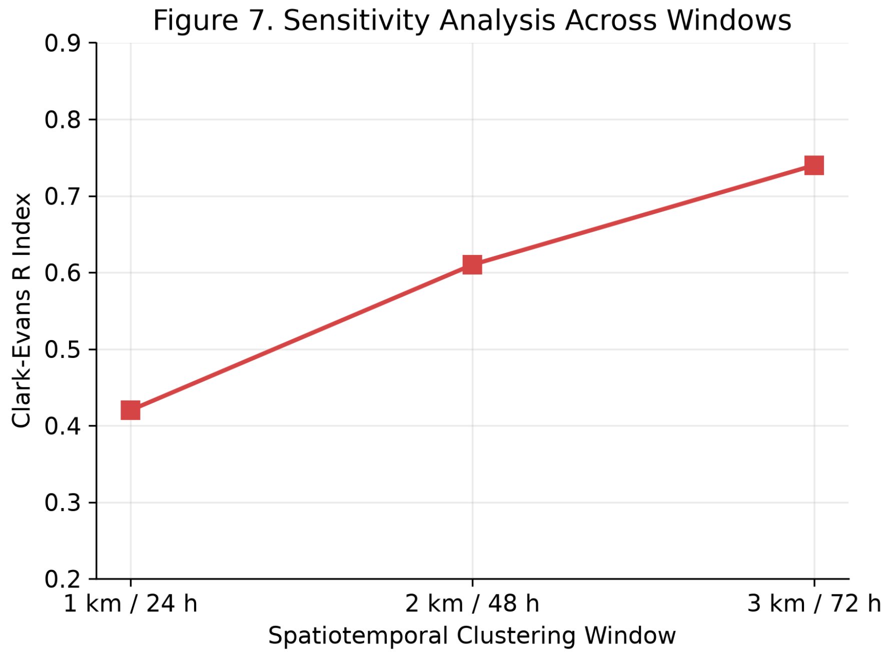

Figure 7. Sensitivity Analysis Across Windows.

Figure 7. Sensitivity of the spatial clustering result to alternative event-definition thresholds. Clark–Evans R remains below unity across all three spatial–temporal clustering configurations, indicating that the detected spatial aggregation is robust to reasonable changes in event-definition parameters.

5. Interpretation

The statistical analyses consistently indicate that wildfire events during 20–24 July 2026 were strongly clustered in space but not in time. Multiple independent statistical approaches — including Clark–Evans nearest-neighbor analysis, Ripley's K-function, and Monte Carlo simulation — produced concordant evidence that wildfire events were significantly more spatially aggregated than expected under Complete Spatial Randomness.

In contrast, the Knox test detected no significant space-time interaction, suggesting that nearby wildfire events did not occur in unusually synchronized temporal patterns after repeated satellite detections had been consolidated into independent wildfire events.

Wildfire events were also found to occur significantly closer to roads and populated places than expected under the Monte Carlo null model. These spatial associations are consistent with increased human accessibility influencing ignition locations, a pattern also reported in prior Mediterranean wildfire research linking ignition risk to proximity to roads and settlements (Romero-Calcerrada et al., 2008). However, they should not be interpreted as direct evidence that fires were deliberately ignited by humans. The analyses quantify spatial association rather than causation and therefore cannot distinguish between deliberate ignition, accidental human ignition, or other processes that may preferentially occur near accessible areas.

Overall, the results support the conclusion that the July 2026 wildfire outbreak exhibited non-random spatial organization strongly associated with accessible landscapes, while lacking evidence of coordinated temporal ignition. These findings are consistent with a wildfire regime shaped by the interaction of environmental conditions and human accessibility rather than by purely random ignition processes or synchronized ignition events, and align with broader Mediterranean wildfire modeling efforts that integrate meteorological, vegetation, and human-activity data (Kondylatos et al., 2023).

Comparisons to wildfire causation findings in other countries (e.g., other Mediterranean nations affected by the same regional heatwave) do not constitute valid evidence for Algeria's specific case: similar fire intensity across countries more often reflects shared climatic conditions than shared cause. Establishing the cause of any individual fire requires direct, case-specific evidence (field investigation, testimony, physical evidence).

6. Limitations

- Null-model sampling domain for proximity tests (Section 3.6) not independently re-confirmed in this final draft — whether random points were drawn from burnable vegetation cover only or the full bounding box. This is the single most important open technical item; resolving it would strengthen (or appropriately temper) the confidence placed in Sections 4.6–4.7.
- Monte Carlo simulation count (99) limits the minimum resolvable empirical p-value to 0.01 for the Clark–Evans, Ripley's K, and proximity tests. Higher simulation counts would provide finer p-value resolution but were not computationally feasible within the present analysis environment.
- Short data window (5 days) relative to official cumulative statistics (20+ days since July 1; 3,719 fires since May 1), meaning this analysis captures only a subset of the season's activity.
- Satellite detection sensitivity (~375 m–1 km resolution, 1–4 overpasses/day) means smaller, quickly-extinguished fires captured in official ground-based counts are likely absent from this satellite-based dataset.
- Incomplete DEM coverage: 26% of raw points were excluded from topographic analysis due to missing SRTM tiles.
- No lightning or wind data included — the most valuable addition for strengthening any natural-vs-human-origin inference, not yet incorporated.
- No comparison of fire terrain distribution against the full study area's terrain distribution (Section 4.5 is descriptive only).
- Correlational, not causal: all results are descriptive-statistical and cannot establish intent, and are not a substitute for field investigation or judicial findings regarding any individual fire.

7. Conclusion

This report presents a methodologically layered analysis of the July 2026 northern Algeria wildfire outbreak: deduplication of satellite detections into independent events, dual-method confirmation of spatial clustering (analytical and Monte Carlo), space-time independence testing, human-accessibility proximity testing, and a three-parameter sensitivity analysis confirming robustness of the main conclusions. Wildfire events were spatially clustered but not temporally coordinated, and were located significantly closer to roads and settlements than random chance would predict — consistent with, but not proof of, human-related ignition influence. Two methodological limitations should be considered when interpreting the results: the sampling domain used for the proximity null model was not independently re-verified, and the Monte Carlo analyses were based on 99 simulations because of computational constraints. These limitations should be addressed in future extensions of the analysis.

8. Data Availability and Reproducibility

Analysis conducted in Python 3 (numpy, pandas, scipy, rasterio, geopandas). All coordinate transformations, clustering thresholds, and Monte Carlo parameters are documented in Section 3 to support full reproducibility by other researchers.

9. References

9.1 Scientific and Data References

Baïle, R., Muzy, J.-F., & Silvani, X. (2020). Multifractal point processes and the spatial distribution of wildfires in French Mediterranean regions. arXiv:2006.02165.

Clark, P. J., & Evans, F. C. (1954). Distance to nearest neighbor as a measure of spatial relationships in populations. *Ecology, 35*(4), 445–453. https://doi.org/10.2307/1931034

Diggle, P. J. (2003). *Statistical Analysis of Spatial and Spatio-Temporal Point Patterns* (3rd ed.). CRC Press.

Knox, E. G. (1964). The detection of space-time interactions. *Journal of the Royal Statistical Society: Series C (Applied Statistics), 13*(1), 25–29. https://doi.org/10.2307/2985220

Kondylatos, S., Prapas, I., Camps-Valls, G., & Papoutsis, I. (2023). Mesogeos: A multi-purpose dataset for data-driven wildfire modeling in the Mediterranean. arXiv:2306.05144.

NASA FIRMS. VIIRS Active Fire Data. NASA Fire Information for Resource Management System — https://firms.modaps.eosdis.nasa.gov

NASA SRTM. Shuttle Radar Topography Mission Global 30 m Digital Elevation Model.

OpenStreetMap contributors. OpenStreetMap data, accessed through Geofabrik Algeria extracts — https://download.geofabrik.de/africa/algeria.html

Ripley, B. D. (1976). The second-order analysis of stationary point processes. *Journal of Applied Probability, 13*(2), 255–266. https://doi.org/10.2307/3212829

Romero-Calcerrada, R., Novillo, C. J., Millington, J. D. A., & Gómez-Jiménez, I. (2008). GIS analysis of spatial patterns of human-caused wildfire ignition risk in the SW of Madrid (Central Spain). *Landscape Ecology, 23*, 341–354. https://doi.org/10.1007/s10980-008-9190-2

Schroeder, W., Oliva, P., Giglio, L., & Csiszar, I. A. (2014). The New VIIRS 375 m active fire detection data product: Algorithm description and initial assessment. *Remote Sensing of Environment, 143*, 85–96. https://doi.org/10.1016/j.rse.2013.12.008

9.2 News and Contextual Sources

Anadolu Agency (AA). Civil Protection wildfire statistics, July 2026.

Global Times/Xinhua; France 24 — Additional regional news coverage of the July 2026 heatwave and wildfire season.

Morocco World News — report on arrests for deliberate ignition near Constantine, July 2026.