# Illegal Mining Detection Using Multi-Temporal Satellite Imagery

PARSEC-6.0

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# 1 Problem Definition and Motivation

Illegal mining is not a single visual event but a slow, cumulative land transformation. It manifests as progressive vegetation loss, increased exposed soil, surface disturbance, and spatial expansion of excavation pits.

Traditional image classification approaches fail because they treat detection as a snapshot problem. This system instead models mining as a persistent physical process evolving over time.

Key challenges addressed:

- Seasonal vegetation changes
- Atmospheric noise and clouds
- Mine size variability
- Legal versus illegal activity distinction

# 2 System Design Philosophy

The system is intentionally conservative. Early stages allow noise, while later stages aggressively validate realism and legality.

Core principle:

> Detect generously early, validate conservatively late.

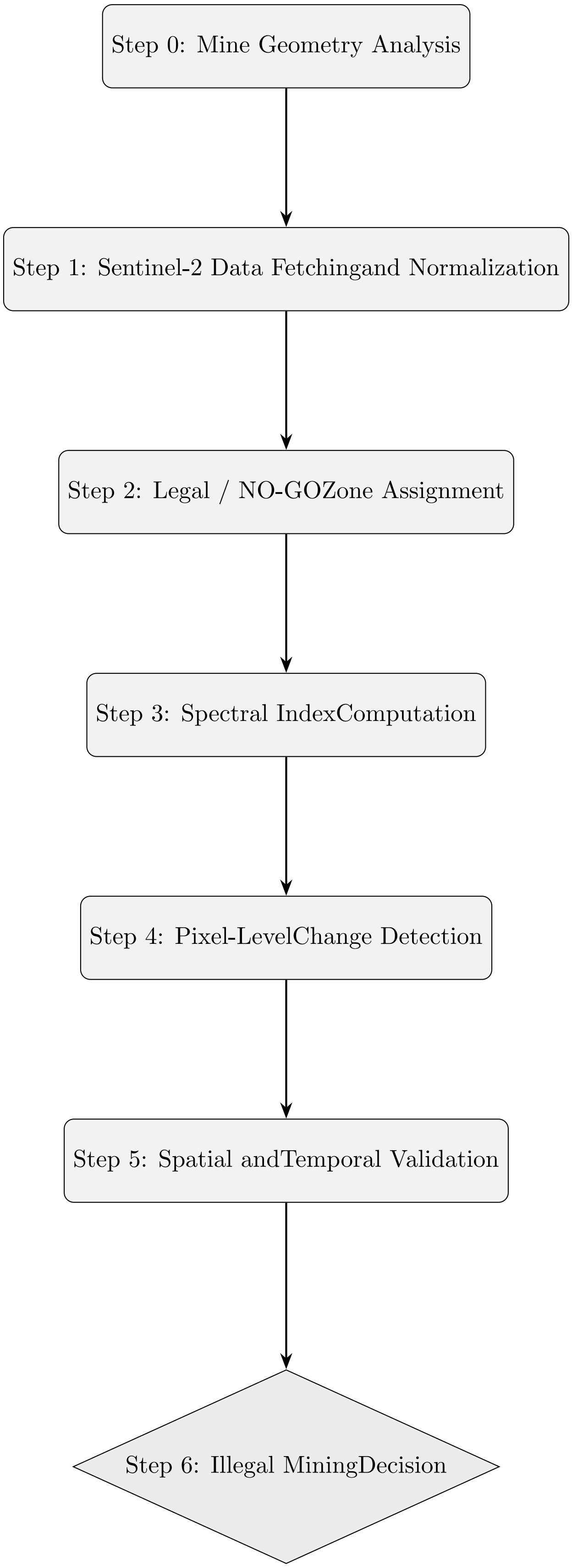


Figure 1: Complete pipeline enforcing physical, spatial, temporal, and legal constraints.

# 3 Step 0: Mine Geometry Analysis

All 506 mine polygons are validated geometrically before any satellite processing.

Operations performed:

- Polygon validity checks
- Area computation
- Spatial distribution analysis
- Bounding box extraction

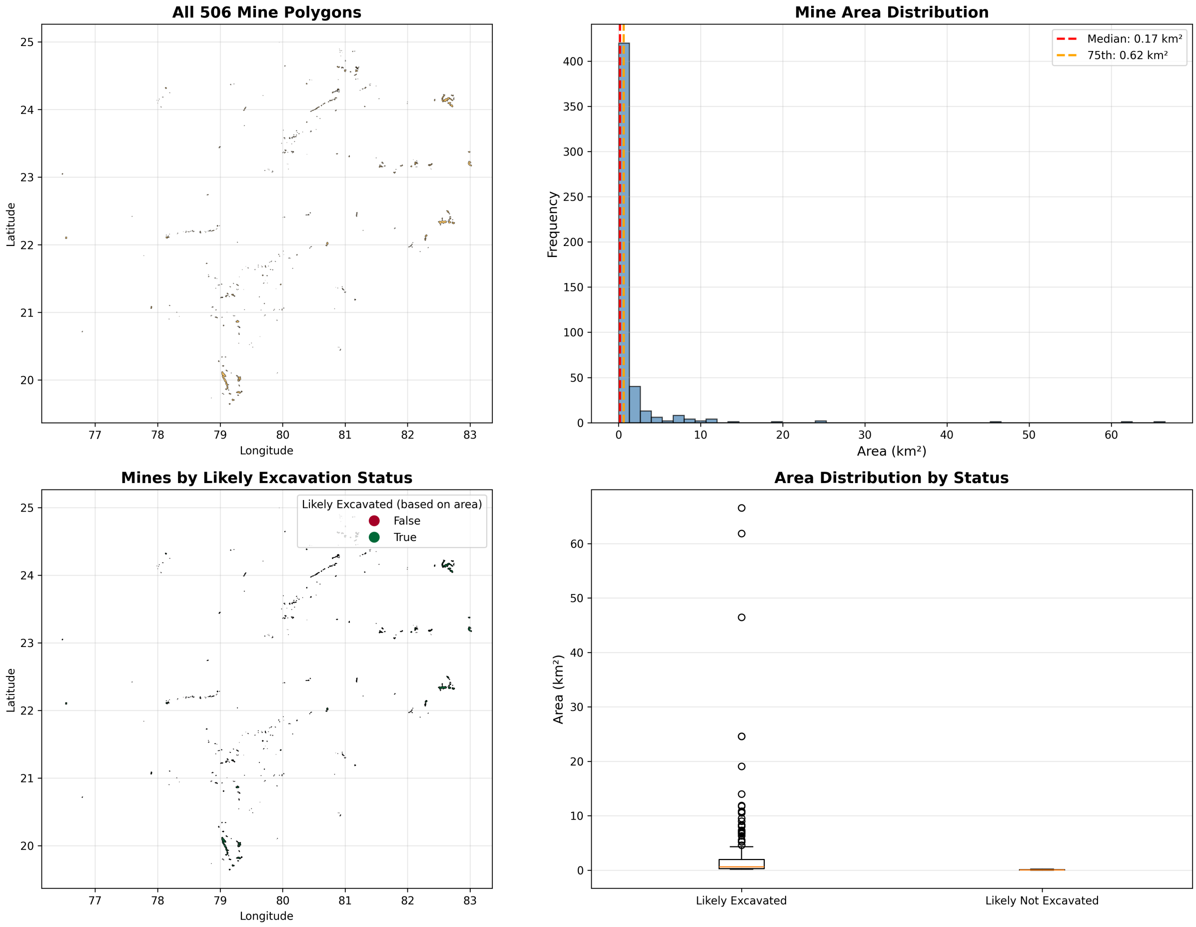


Figure 2: Mine spatial distribution, area histogram, and heuristic excavation likelihood based on polygon area.

The heuristic excavation indicator is exploratory only and not used in final detection.

# 4 Step 1: Sentinel-2 Data Acquisition and Normalization

For each mine and timestamp:

- Sentinel-2 imagery is fetched
- Required spectral bands are extracted

- Data is resampled to a fixed 512 × 512 grid

This normalization ensures pixel-wise comparability across mines of vastly different sizes. Approximate spatial resolution: **2.7 m per pixel**.

# 5 Step 2: Legal and NO-GO Zone Assignment

Each mine is classified as:

- LEGAL (356 mines)
- NO-GO (150 mines)

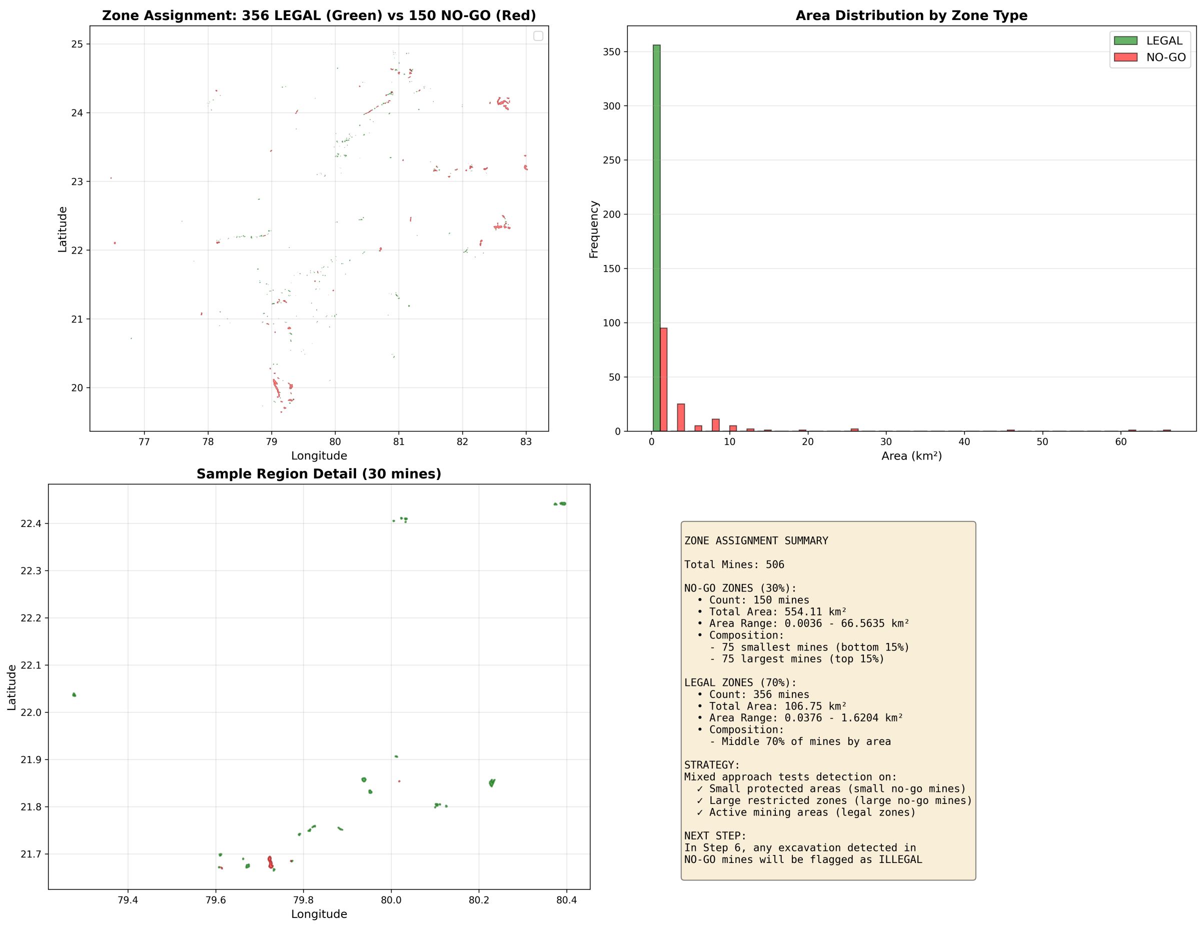


Figure 3: Spatial distribution of LEGAL and NO-GO mines.

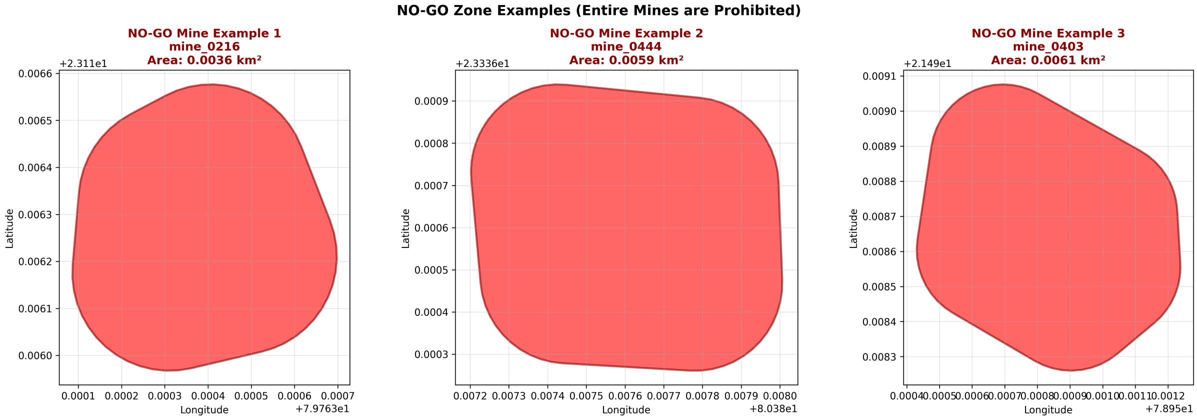


Figure 4: Representative NO-GO mine geometries where any excavation is illegal.

This separation ensures detection and legality are decoupled.

# 6 Step 3: Spectral Index Computation

Indices computed per pixel:

$$\text{NDVI} = \frac{NIR - RED}{NIR + RED} \quad \text{NBR} = \frac{NIR - SWIR}{NIR + SWIR}$$

$$\text{NDMI} = \frac{NIR - SWIR}{NIR + SWIR} \quad \text{SI} = \frac{RED + SWIR}{2}$$

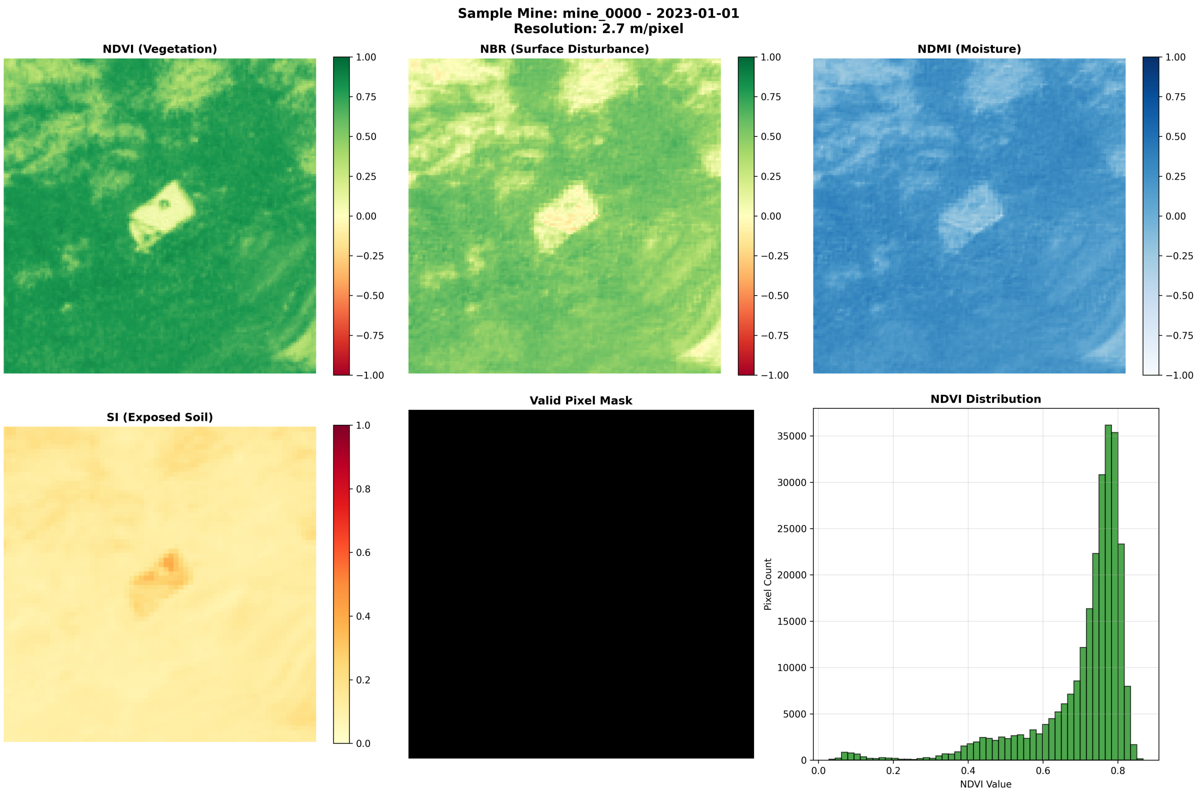


Figure 5: Spectral indices highlighting vegetation loss and exposed soil.

# 7 Step 4: Pixel-Level Change Detection

Between consecutive timestamps:

- Differential indices are computed
- A disturbance score is formed
- Gaussian Mixture Model clustering isolates disturbed pixels

This step intentionally allows false positives.

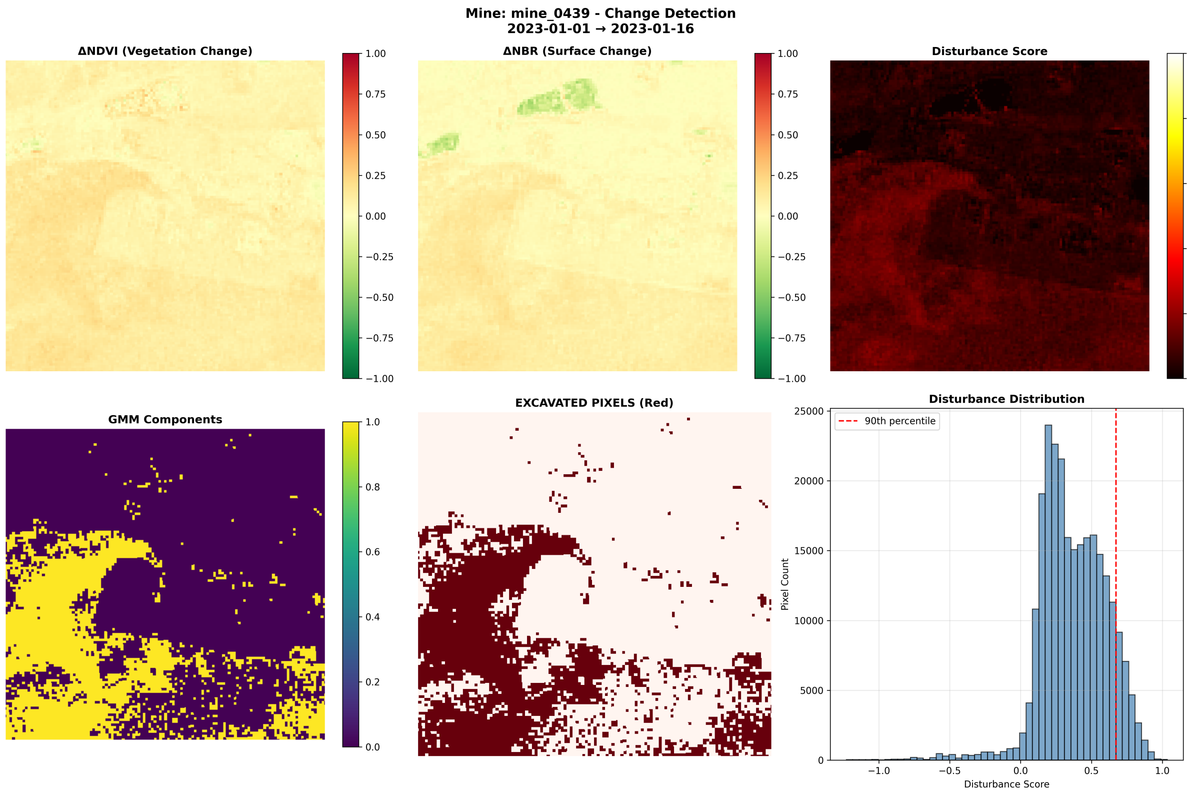


Figure 6: Change detection, disturbance score distribution, and excavation candidates.

# 8 Step 5: Spatial and Temporal Validation

Spatial coherence is enforced using connected components.

Temporal realism is enforced using a monotonic envelope:

$$A_t = \max(A_0, A_1, \ldots, A_t)$$

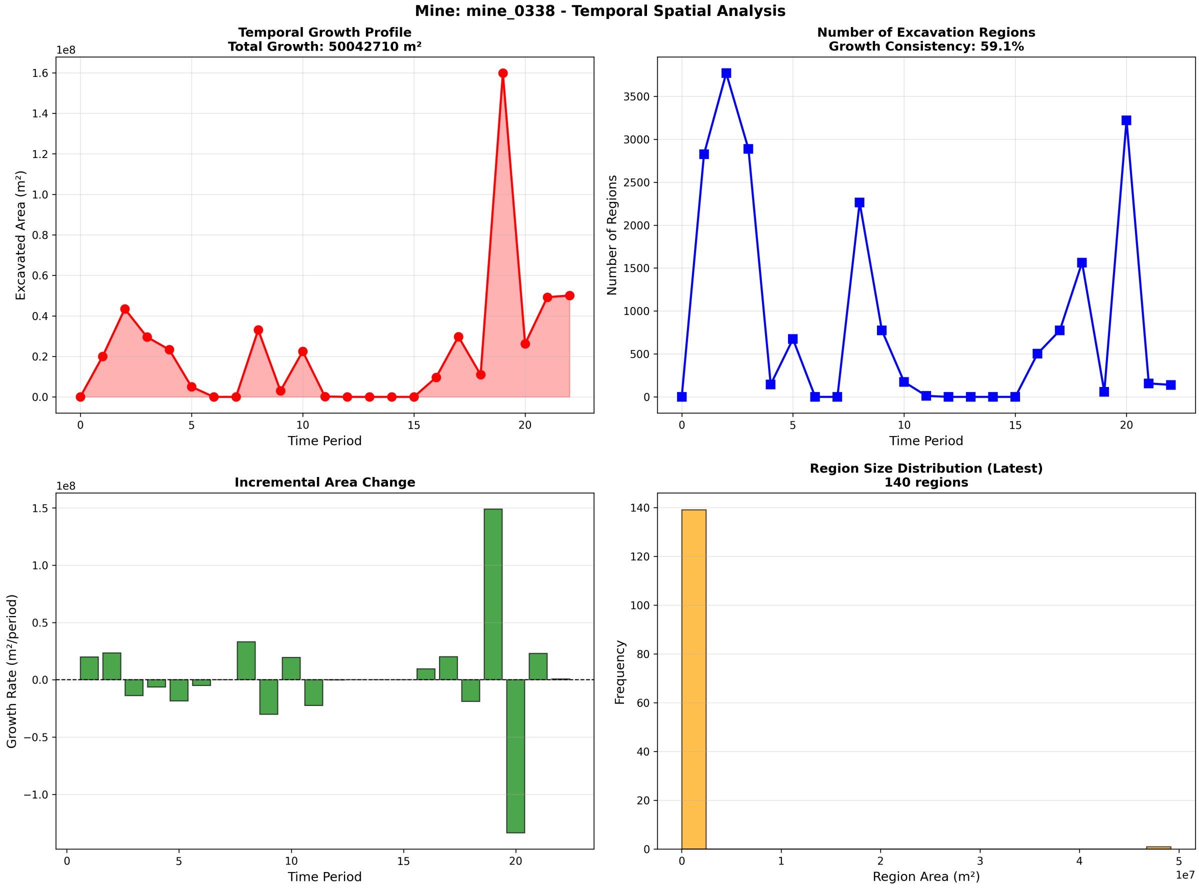


Figure 7: Temporal excavation growth, region count, and growth consistency.

Growth consistency filters spurious detections.

# 9 Step 6: Illegal Mining Decision

A mine is flagged illegal if:

1. Excavation exists
2. Growth is persistent
3. Mine lies in a NO-GO zone

The first violating timestamp is recorded as the violation onset.

# 10 System-Level Results

| | |
|---|---|
| Total Mines | 506 |
| LEGAL Mines | 356 |
| NO-GO Mines | 150 |
| Mines with Activity | 91 |
| Illegal Violations | 25 |
| Average Growth Consistency | 59.7% |

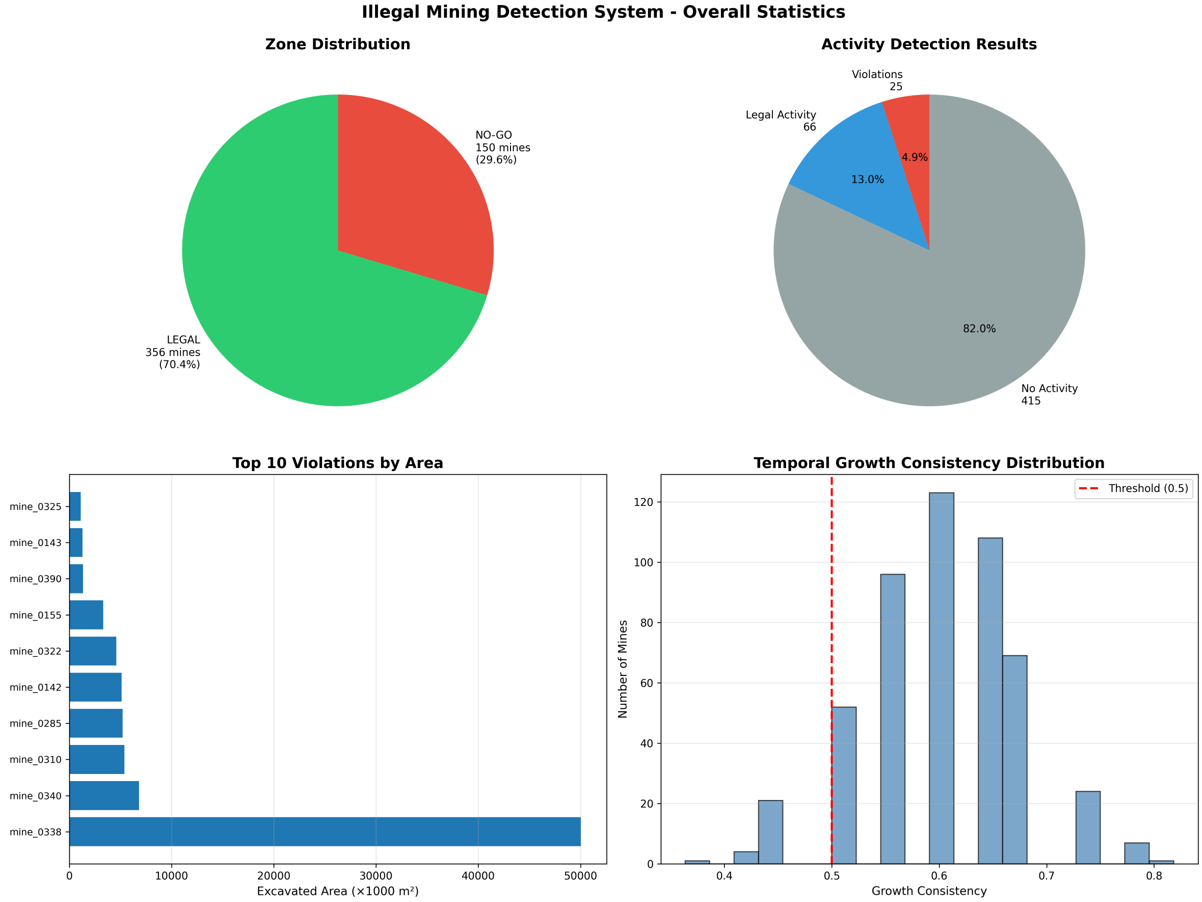


Figure 8: Overall system statistics and violation distribution.

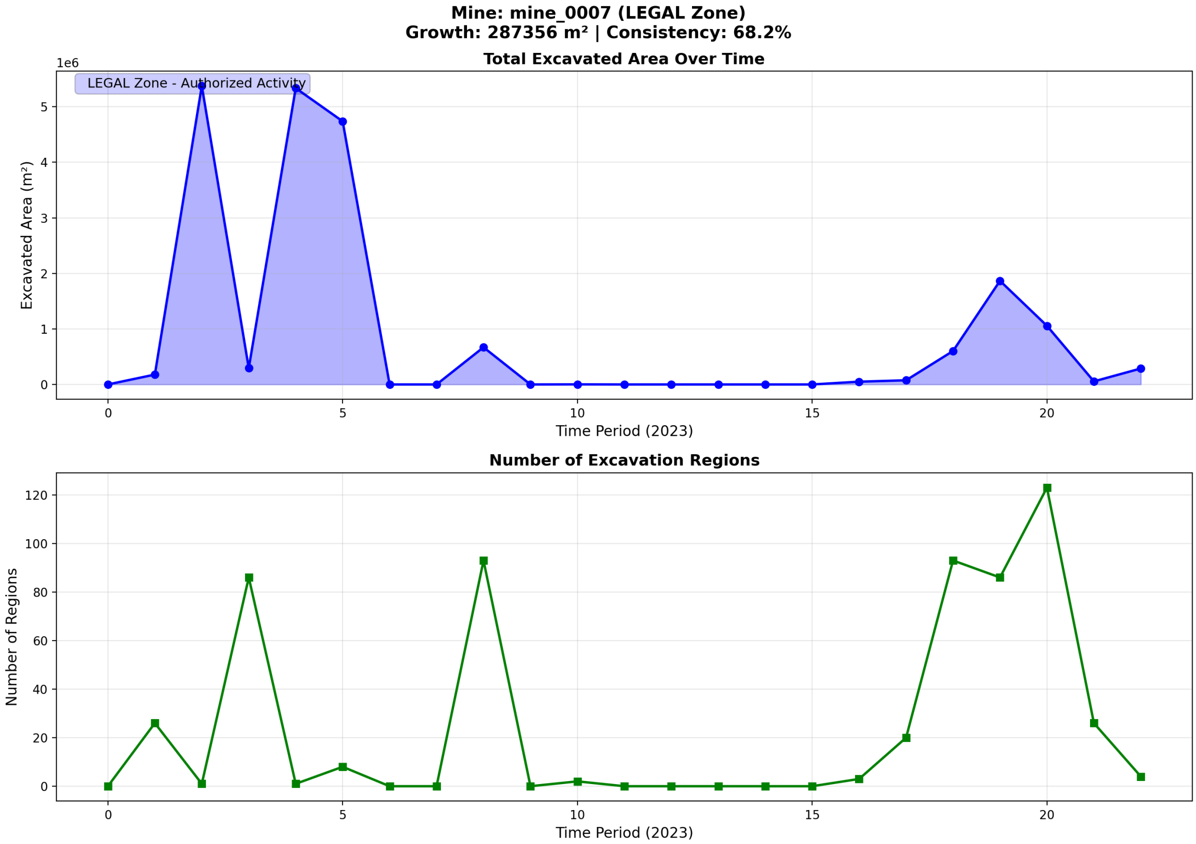


Figure 9: Example LEGAL mine showing consistent, authorized excavation.

## 11 Limitations

- Cloud and shadow contamination
- Sentinel-2 spatial resolution limits
- No labeled ground truth
- Partial land reclamation not modeled

## 12 Conclusion

This work demonstrates that illegal mining can be detected without labeled data by enforcing physical realism, spatial coherence, temporal persistence, and legal constraints. The system is interpretable, auditable, and suitable for regulatory monitoring.