Tree Cutting Priority Analysis for Fire Creek

Project: Spatial Data Analysis - Homework 2
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Executive Summary

This project calculates and prioritizes tree cutting zones for wildfire risk mitigation in the Fire Creek area using Python-based spatial analysis with GeoPandas and matplotlib visualization.

Key Results:

- **Zones Analyzed:** 80 cutting grid zones
- **Method:** Multi-criteria decision analysis (MCDA) using five weighted factors
- **Normalization:** Scores scaled 0-100
- **Priority Classes:** High, Medium, Low

Key Metrics:

- Mean Priority Score: 29.37
- Maximum Priority Score: 60.73 (Grid 163)
- Standard Deviation: 13.71

Distribution:

- Critical Priority: 0 zones (0.0%)
- High Priority: 5 zones (6.3%)
- Medium Priority: 43 zones (53.8%)
- Low Priority: 32 zones (40.0%)

Outputs: Complete visualization with 3 analytical charts and spatial data files

1. Introduction

1.1 Objectives

The primary objective is to calculate tree cutting priority for each zone using Multi-Criteria Decision Analysis (MCDA) in Python/GeoPandas to support wildfire risk mitigation efforts in the Fire Creek area.

Analysis Factors & Weights:

- Tree Mortality: 30%
- Community Features: 15%
- Egress Routes: 20%
- Populated Areas: 20%
- Electric Utilities: 15%

1.2 Tools and Technologies

- **Python 3.x** - Core programming language
- **GeoPandas** - Spatial analysis and operations
- **Pandas / NumPy** - Data processing and mathematical operations
- **Matplotlib** - Charts and visualization generation
- **QGIS 3.16+** - Geographic visualization and mapping
- **Shapefile / GeoPackage** - Spatial data formats

2. Data and Study Area

2.1 Study Area

Location: Fire Creek Area
Spatial Reference System: EPSG:26711
Analysis Units: 80 grid zones

2.2 Input Data Schema

Dataset	Features	Description
CuttingGrids	80	Grid polygons defining cutting zones
SBNFMortality	12	Tree mortality polygons with total mortality values
CommunityFeature	8	Locations of critical community infrastructure
EgressRoutes	6	Emergency evacuation route lines
PopulatedAreas	6	Residential / populated area polygons
Electric Utilities	5 layers	Transmission, SubTransmission, Distribution Circuits, Substations, PoleTopSubs

3. Methodology

3.1 Analysis Workflow

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Initial Dataset (80 Grid Zones + 5 Risk Factors)
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┌─────────────────────────────────────────────┐
│ STEP 1: Load & Align CRS → EPSG:26711      │
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                 │
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┌─────────────────────────────────────────────┐
│ STEP 2: Calculate Mortality Score          │
│ → Spatial intersection with mortality data│
│ → Normalize 0-100                           │
└─────────────────────────────────────────────┘
                 │
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┌─────────────────────────────────────────────┐
│ STEP 3: Calculate Community Score          │
│ → Count community features per zone         │
│ → Normalize 0-100                           │
└─────────────────────────────────────────────┘
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│ STEP 4: Calculate Egress Score             │
│ → Measure route coverage per zone           │
│ → Normalize 0-100                           │
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┌─────────────────────────────────────────────┐
│ STEP 5: Calculate Populated Score          │
│ → Assess residential area exposure          │
│ → Normalize 0-100                           │
└─────────────────────────────────────────────┘
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┌─────────────────────────────────────────────┐
│ STEP 6: Calculate Utility Score            │
│ → Evaluate 5 utility layer exposures        │
│ → Normalize 0-100                           │
└─────────────────────────────────────────────┘
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│ STEP 7: Apply Weighted MCDA                │
│ → Priority Score = Σ(weight × score)       │
│ → Final score range: 0-100                 │
```

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│ STEP 8: Classify Priority                     │
│ → Low / Medium / High / Critical               │
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│ STEP 9: Generate Visualizations               │
│ → Bar Chart, Pie Chart, Top 10 Chart          │
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3.2 MCDA Approach

The analysis employs a weighted Multi-Criteria Decision Analysis approach where:

- Each factor is independently calculated and normalized to a 0-100 scale
- Weighted summation produces the final priority score
- Higher scores indicate higher priority for tree cutting operations

3.3 Normalization Formula

For each criterion, raw scores are normalized using:

```
Normalized Score = (Raw Score / Maximum Raw Score) × 100
```

This ensures all factors contribute proportionally to the final priority score regardless of their original measurement units.

4. Scoring Criteria

4.1 Overview of Criteria

Criterion	Weigh	Description
Tree Mortality	30%	Spatial intersection with mortality polygons
Community Features	15%	Presence of critical community infrastructure
Egress Routes	20%	Coverage of evacuation routes
Populated Areas	20%	Exposure of residential areas
Electric Utilities	15%	Exposure of utility infrastructure

4.2 Criterion 1: Tree Mortality (30%)

Rationale: Dead and dying trees pose the highest direct fire risk, serving as fuel sources that can accelerate wildfire spread and intensity.

Implementation:

- Spatial intersection between cutting grids and mortality polygons
- Sum of total mortality values within each zone
- Higher mortality values indicate greater immediate risk

Impact: Primary driver of priority scores, reflecting direct fire hazard from dead vegetation.

4.3 Criterion 2: Community Features (15%)

Rationale: Protection of critical infrastructure including schools, fire stations, hospitals, and community centers is essential for public safety and emergency response capability.

Implementation:

- Count of community features within or near each zone
- Binary scoring for presence/absence of critical facilities
- Proximity weighting for features near zone boundaries

Impact: Ensures protection of community assets vital for evacuation and emergency services.

4.4 Criterion 3: Egress Routes (20%)

Rationale: Clear evacuation routes are life-critical during wildfire events. Tree removal along escape corridors prevents route blockage and ensures safe evacuation.

Implementation:

- Calculate length of egress routes passing through each zone
- Higher coverage indicates greater importance for evacuation safety
- Line intersection analysis with grid zones

Impact: Prioritizes zones that, if left unmanaged, could block evacuation pathways.

4.5 Criterion 4: Populated Areas (20%)

Rationale: Residential areas face direct threat from wildfire. Tree cutting creates defensible space around homes and reduces ember ignition risks.

Implementation:

- Measure overlap between populated area polygons and cutting zones

- Area-based scoring reflecting population exposure
- Higher scores for zones with greater residential coverage

Impact: Protects human life and property by creating fire breaks near homes.

4.6 Criterion 5: Electric Utilities (15%)

Rationale: Utility infrastructure poses dual risk: power lines can spark fires, and fires can damage critical electrical infrastructure causing widespread outages.

Electric Utility Scoring Details:

Utility Type	Weigh	Method
Transmission Lines	3.0	Length × weight × priority
SubTransmission Lines	2.5	Length × priority
Distribution Circuits	2.0	Length within zone
Substations	3.0	Fixed score × priority
Pole Top Substations	2.0	Count × fixed score

Implementation:

- Multi-layer analysis across 5 utility datasets
- Weighted scoring based on voltage level and criticality
- Length-based calculations for linear features (power lines)
- Count-based calculations for point features (substations)

Impact: Reduces fire ignition risk from electrical equipment and protects power grid reliability.

5. Priority Classification

5.1 Classification System

Priority Class	Score Range	Action Required	Description
Critical	75-100	Immediate action	Emergency response within days
High	50-74	Near-term action	Schedule within current season
Medium	25-49	Scheduled maintenance	Address in annual work plan
Low	0-24	Routine monitoring	Monitor and reassess periodically

5.2 Weighted Priority Formula

The final priority score for each zone is calculated as:

```
priority_score = (0.3 × mortality_score) +
                 (0.15 × community_score) +
                 (0.2 × egress_score) +
                 (0.2 × populated_score) +
                 (0.15 × utility_score)
```

Where each component score is normalized to 0-100 scale before weighting.

6. Results and Analysis

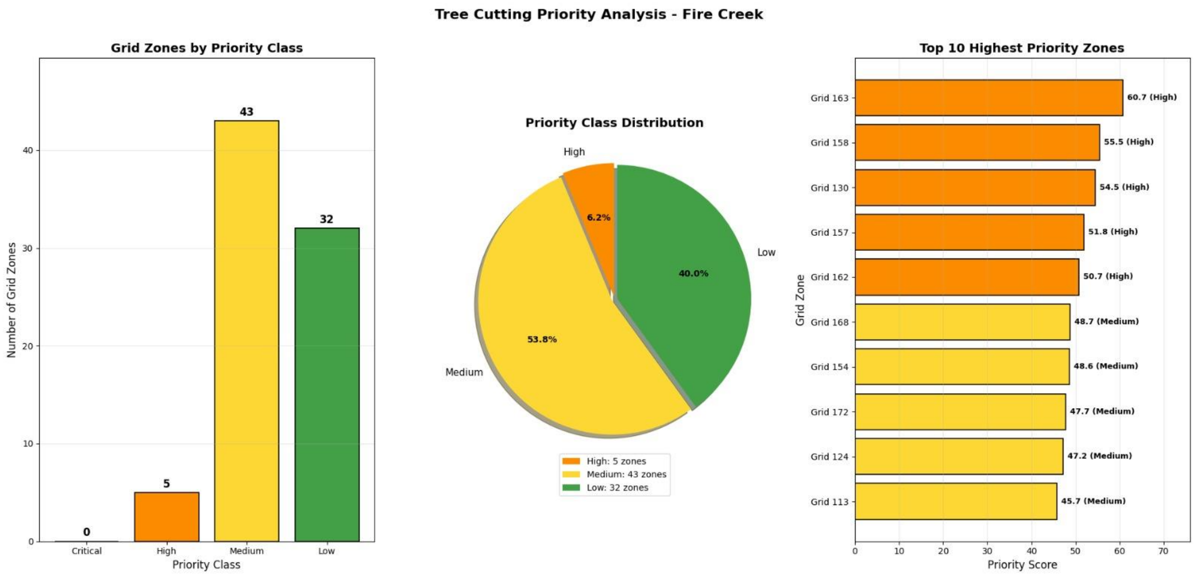
6.1 Priority Distribution

Analysis Results:

Class	Coun	Percentage	Cumulative
Critical	0	0.0%	0.0%
High	5	6.3%	6.3%
Medium	43	53.8%	60.0%
Low	32	40.0%	100.0%
Total	**80**	**100%**	-

Key Insights:

- No zones reached critical threshold (75+), indicating manageable overall risk
- Only 5 zones (6.3%) require near-term action
- Majority (53.8%) fall into medium priority requiring scheduled maintenance
- 40% are low priority suitable for routine monitoring



6.2 Score Statistics

Statistical Summary:

Metric	Value	Interpretation
Mean Priority Score	29.37	Average zone falls in medium-low range
Maximum Priority Score	60.73	Highest risk zone (Grid 163)
Minimum Priority Score	8.16	Lowest risk zone
Standard Deviation	13.71	Moderate variability across zones
Median	26.45	Central tendency near mean

Distribution Characteristics:

- Right-skewed distribution with concentration in 20-40 score range
- No extreme outliers above 65 points
- Relatively consistent risk levels across most zones

6.3 High Priority Zones

Top 5 Zones Requiring Near-Term Action:

Rank	Grid ID	Score	Class	Key Risk Factors
1	163	60.73	High	High mortality, egress route coverage
2	158	55.51	High	Community features, utility exposure
3	130	54.48	High	Populated area proximity, mortality
4	157	51.84	High	Multiple utility layers, egress routes
5	162	50.74	High	Balanced risk across all factors

Operational Recommendations:

- Grid 163 should be addressed first (highest score)
- All five zones should be scheduled within current fire season
- Field verification recommended for final work planning

6.4 Top 10 Priority Zones

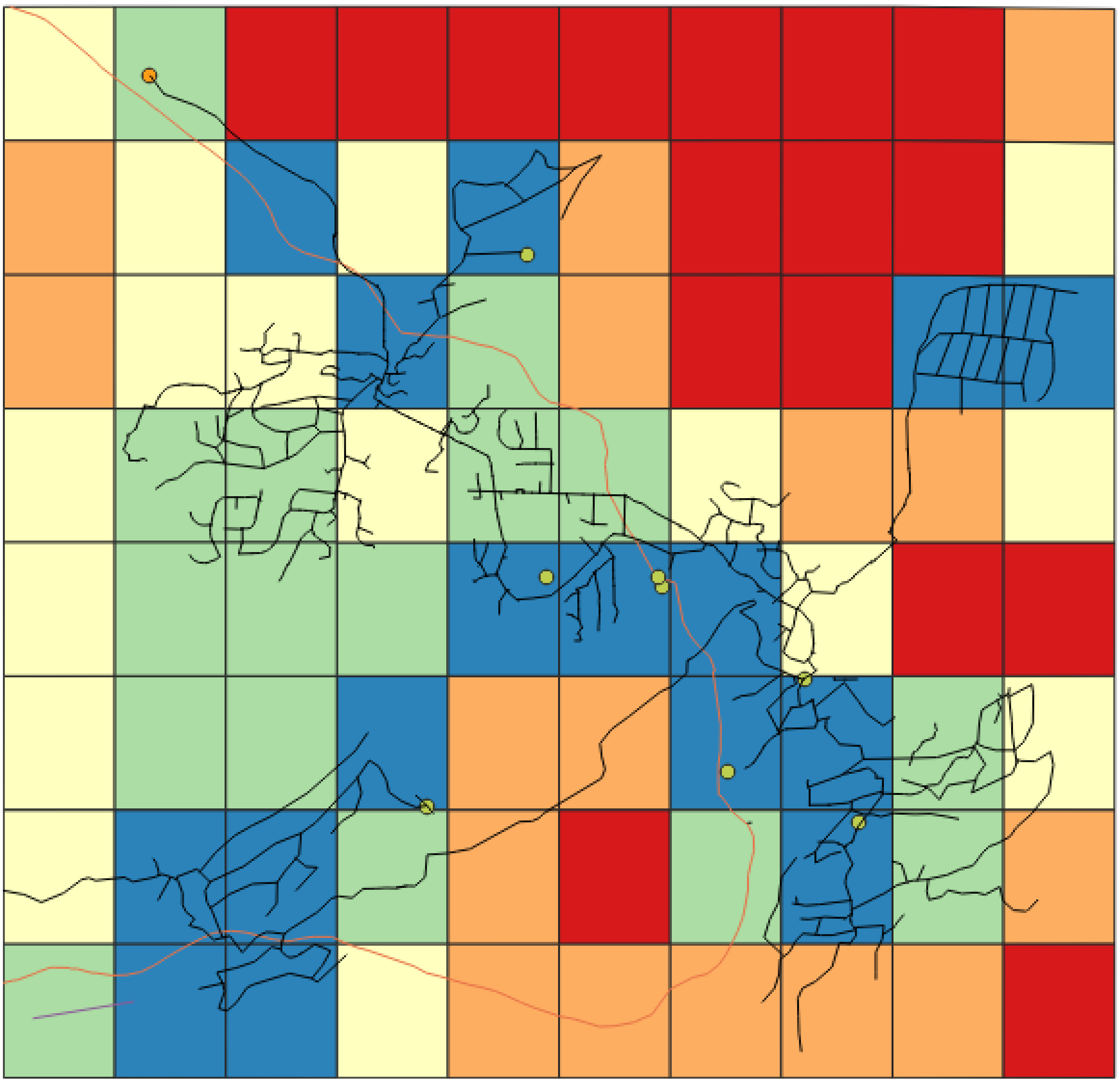
Extended Priority List:

Rank	Grid ID	Priority Score	Class	Notes
1	163	60.73	High	Top priority
2	158	55.51	High	Secondary priority
3	130	54.48	High	Community protection focus
4	157	51.84	High	Utility corridor
5	162	50.74	High	Egress route critical
6	168	48.69	Medium	Near high threshold
7	154	48.57	Medium	Consider for early action
8	172	47.73	Medium	Moderate risk balanced
9	124	47.21	Medium	Monitor for escalation
10	113	45.70	Medium	Standard maintenance

Planning Considerations:

- Zones 6-10 are medium priority but near high threshold
- Consider advancing zones 6-7 if resources permit
- Group adjacent zones for operational efficiency

6.5 Spatial Analysis



Spatial Patterns Observed:

- High priority zones clustered in central-eastern portion of study area
- Spatial correlation with populated areas and utility corridors
- Linear patterns following egress routes and transmission lines
- Low priority zones concentrated in peripheral areas with less infrastructure

7. Visualization and Outputs

7.1 Chart Types

Three complementary visualizations were generated to support decision-making:

1. **Bar Chart - Grid Zones by Priority Class**

    a. Shows count of zones in each priority category
    b. Highlights the 43 medium-priority zones requiring scheduled attention
    c. Confirms no critical zones requiring emergency response
2. **Pie Chart - Priority Class Distribution**
    a. Percentage breakdown: Low (40%), Medium (53.8%), High (6.2%)
    b. Visual representation of overall risk profile
    c. Demonstrates manageable risk distribution
3. **Horizontal Bar Chart - Top 10 Highest Priority Zones**
    a. Individual zone scores with Grid IDs
    b. Color-coded by classification (orange for high, yellow for medium)
    c. Facilitates crew assignment and work scheduling

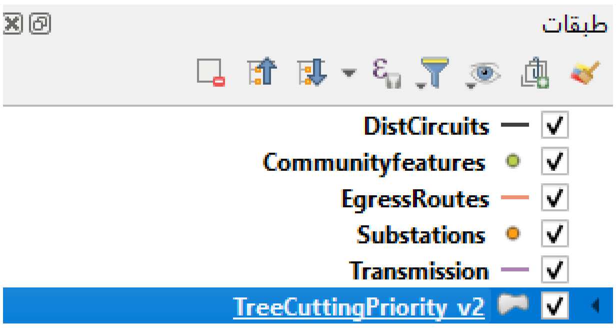
7.2 Color Scheme

Consistent color coding used across all visualizations:

Priority Class	Color	Application
Critical	Red	Emergency zones (none in current analysis)
High	Orange	Near-term action (5 zones)
Medium	Yellow	Scheduled maintenance (43 zones)
Low	Green	Routine monitoring (32 zones)

Chart Output: TreeCuttingPriority_Charts.png (300 DPI, publication quality)

7.3 QGIS Visualization



Loading Priority Results in QGIS

Method 1: Add Shapefile

1. Layer → Add Layer → Add Vector Layer
2. Browse to TreeCuttingPriority_[timestamp].shp
3. Click Add to load into map canvas

Method 2: Add GeoPackage

1. Layer → Add Layer → Add Vector Layer

2. Select TreeCuttingPriority_[timestamp].gpkg
3. Choose layer from package if multiple layers present

Styling by Priority Class

Categorized Symbology:

- Right-click layer → Properties → Symbology
- Select "Categorized" renderer
- Field: `prior_cls` (priority class)
- Click "Classify" to auto-generate classes
- Assign colors:
  - Critical → Red, opacity 70%
  - High → Orange, opacity 70%
  - Medium → Yellow, opacity 60%
  - Low → Green, opacity 60%
- Adjust outline: Black, 0.5pt width

Alternative: Graduated Colors

- Field: **`priority_s`** (priority score)
- Mode: Pretty Breaks, 4 classes
- Color Ramp: RdYlGn (inverted - red high, green low)
- Manual adjustments for breakpoints: 0-25, 25-50, 50-75, 75-100

8. Conclusions and Recommendations

Summary

This GeoPandas-based spatial analysis successfully evaluated all 80 Fire Creek cutting zones using multi-criteria decision analysis. The systematic approach:

✓ Applied five weighted risk factors using industry-standard wildfire mitigation criteria

✓ Normalized all scores to comparable 0-100 scale

✓ Identified 5 high-priority zones requiring near-term action

✓ Classified 43 zones for scheduled maintenance programs

✓ Produced reproducible, data-driven results through documented Python workflows

✓ Generated professional visualizations for stakeholder communication

Strengths of Analysis:

- **Objectivity** - Mathematical criteria eliminate subjective bias in prioritization
- **Transparency** - Weighted formula clearly documented and auditable
- **Spatial Intelligence** - Geographic relationships drive meaningful risk assessment
- **Actionable Results** - Clear priority classes support operational planning
- **Reproducibility** - Python code enables reanalysis with updated data

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Course: Spatial Data Analysis
Assignment: Homework 3 - Tree Cutting Priority Analysis
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END OF REPORT