Terrain Analysis: Ranchos Palos Verdes Landslides

Mara Zwicker
2/16

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* *All figures at the bottom*

Programs Used: ArcGIS Pro, RStudio

Packages Used: terra, tmap, suntools, qgisprocess, RColorBrewer

1. Introduction & Objective

- **Why Landslides?** Rancho Palos Verdes has a history of slope instability.
- **What's Being Analyzed?** The impact of slope change on landslide risk.
- **Objective:** To create a Landslide Susceptibility Map based on terrain slope change from 2000 to 2018.

2. Data Collection

Dataset	Description	Source
DEM (2000 & 2018)	Elevation data to compute slope change	USGS, HydroSHEDS
Fault Lines	Fault proximity as a landslide factor	USGS Quaternary Faults
Drainage Network	Water saturation impact on slopes	HydroSHEDS

3. Terrain Analysis Using R

Instead of using ArcGIS Pro or QGIS, I used R to compute terrain attributes and visualize them on a hillshade. The DEM (2018) was processed to generate slope, aspect, and three types of curvature (profile, plan, and mean). These layers were then overlaid on a hillshade to better visualize topographic patterns and potential landslide-prone areas.

Terrain Attribute Observations

Each terrain attribute provides unique insights into the landscape and its role in **landslide susceptibility**.

1. Slope Map

- **What's Interesting?**
  The slope map clearly highlights steep cliffs and hills in Rancho Palos Verdes, particularly near the coastal areas and fault lines. These areas are known to be at high risk for landslides.
- **Surprising Aspects?**
  Some inland areas exhibit steep slopes that I did not expect. I initially thought landslide-prone zones would be concentrated near the coast, but the data shows instability inland as well.
- **Is It Useful?**
  Yes, slope is a crucial factor in landslide risk because steeper areas have a higher likelihood of failure. The slope change over time will be especially important in identifying increasing risk zones.

2. Aspect Map

- **What's Interesting?**
  The aspect map reveals how slopes are oriented across the study area. I can see that south-facing slopes are dominant, which means they receive more sunlight.
- **Surprising Aspects?**
  The high variation in aspect directions suggests complex terrain structure, which I didn't anticipate in some areas. The mix of north and south facing slopes might indicate past geological activity.
- **Is It Useful?**
  Aspect is useful but secondary to slope. It can provide insights into erosion, water flow, and sun exposure, which influence soil stability and vegetation cover, both factors in landslide risk.

3. Profile Curvature Map

- **What's Interesting?**
  Profile curvature helps distinguish between concave and convex slopes, indicating areas of erosion or deposition.
- **Surprising Aspects?**
  Some areas that I expected to be more stable actually have strong concave curvature, meaning they are zones of water accumulation and potential erosion.
- **Is It Useful?**
  Yes, because it helps identify areas where water collects, this increases soil saturation, which can trigger landslides.

4. Plan Curvature Map

- **What's Interesting?**
  The plan curvature map highlights ridge and valley structures, showing where water is likely to flow or diverge.
- **Surprising Aspects?**
  Some valleys are more sharply defined than expected, which might indicate subsurface erosion or past landslides.
- **Is It Useful?**
  Yes, because it helps predict water flow paths. Water moving through concave areas can destabilize slopes over time.

5. Mean Curvature Map

- **What's Interesting?**
  This map combines both profile and plan curvature to show general terrain roughness.
- **Surprising Aspects?**
  Some regions have unexpectedly high curvature values, suggesting that ruggedness and micro-topography play a larger role than I initially thought.
- **Is It Useful?**
  Yes, because rougher terrain may be more prone to erosion and slope failure.

4. Data Preprocessing

1. Reproject all layers to NAD 1983 UTM Zone 11N for spatial consistency.
2. Clip Fault & Drainage Data to match the DEM extent.
3. Generate Slope from DEM (2000 & 2018):
   - Spatial Analyst → Surface → Slope

5. Computing Slope Change

1. Subtract 2000 Slope from 2019 Slope
   - Slope_Change = Slope_2019 - Slope_2000
2. Output: Slope_Change.tif
   - Identifies areas where terrain steepness has increased or decreased over time.

6. Using Slope Units Instead of Grid Cells

1. Derive Slope Units from DEM
   - Use Flow Direction and Flow Accumulation to extract stream networks.
2. Perform Watershed Analysis
   - Segment the terrain into natural slope units.
3. Convert Watershed Outputs into Polygons
   - This ensures natural terrain segmentation instead of artificial grid cells.

4. Apply Slope Change Analysis Within Each Slope Unit
    - Aggregates slope change values more accurately compared to a grid-based approach.

7. Generating Distance Rasters

1. Compute Distance to Faults
    - Spatial Analyst → Distance → Euclidean Distance
    - Output: Faults_Distance.tif
2. Compute Distance to Drainage
    - Euclidean Distance from Stream Network
    - Output: Drainage_Distance.tif

8. Reclassifying Input Factors

Standardized Scale (1–4 Risk Level)]		
Factor	**1 (Low Risk)**	**4 (High Risk)**
Slope Change (°)	0–5°	>30°
Current Slope (°)	0–15°	>45°
Distance to Faults (m)	>2000m	0–500m
Distance to Drainage (m)	>300m	0–50m

* *All rasters must be reclassified before weighted overlay.*

9. Weighted Overlay Analysis

1. Open Weighted Overlay Tool
2. Set Reclassified Rasters & Weights
    - Slope (Current): 55%
    - Slope Change: 20%
    - Distance to Faults: 10%
    - Distance to Drainage: 15%
3. Run Analysis & Generate Landslide_Susceptibility.tif

10. Final Landslide Susceptibility Map

Map Layout Includes:

- Landslide Susceptibility Classes (Low, Moderate, High, Extreme)
- Legend, Scale Bar, & North Arrow
- Export as high quality JPEG for Reporting

Conclusion & Findings

Summary:

- Slope change is a critical landslide factor.
- Fault & drainage proximity enhance landslide susceptibility.
- GIS-based Weighted Overlay successfully predicts risk zones.

Next Steps: Expand analysis with rainfall, land cover, or soil type.

To fully answer the question of landslide susceptibility in Rancho Palos Verdes, additional terrain analysis is necessary beyond slope, aspect, and curvature. One key factor to consider is hydrology and soil moisture, as water infiltration significantly affects slope stability. Incorporating the Topographic Wetness Index (TWI) would help identify areas prone to water accumulation, while integrating historical rainfall data could highlight zones where precipitation has played a role in past landslides. Additionally, analyzing soil composition and permeability would refine the model by identifying regions where water retention increases instability.

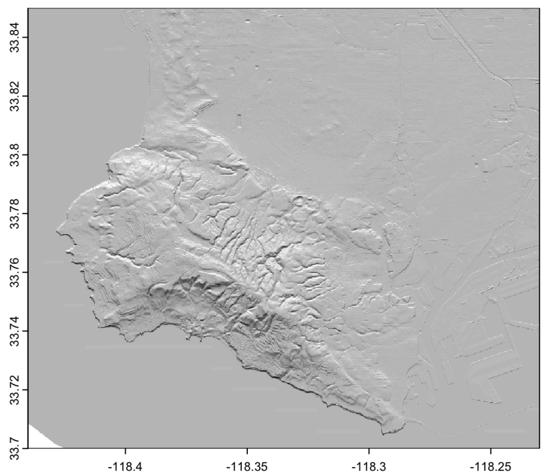
Another important consideration is terrain roughness and geological strength. While curvature maps reveal concave and convex slopes, using Terrain Ruggedness Index (TRI) or Vector Ruggedness Measure (VRM) could provide better insights into surface irregularities. These measures would help distinguish highly fractured, unstable terrain from more stable regions. Furthermore, incorporating fault density and rock strength data could enhance the model by identifying areas where underlying geology contributes to slope failure.

Validating the model with historical landslide data is also essential. Overlaying known landslide locations with the susceptibility map would help assess whether the model correctly predicts high-risk areas. This validation process would allow for fine tuning the weighted overlay analysis, improving its accuracy. Additionally, dividing the study area into sub-regions, such as coastal cliffs versus inland hills, could reveal localized patterns of instability, ensuring that different terrain types are assessed appropriately.

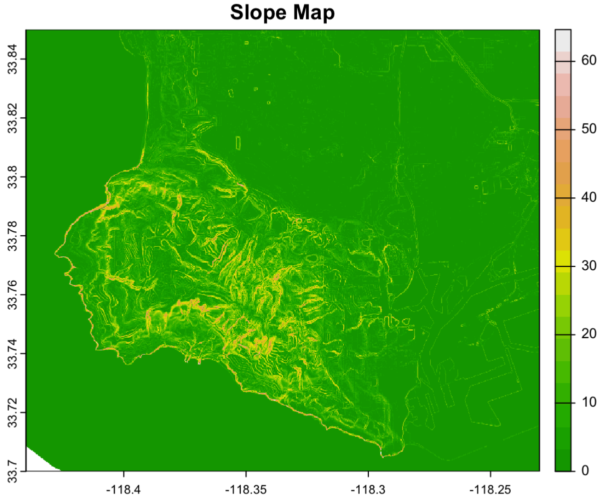
Finally, statistical analysis could strengthen the findings by identifying relationships between terrain variables. Performing a correlation analysis between slope, curvature, and fault proximity would highlight which factors most strongly influence landslide risk. More advanced methods, such as logistic regression or machine learning models, could improve the ability to predict high-risk areas based on past landslide occurrences. By integrating these additional analyses, the final landslide susceptibility model would provide a more comprehensive and accurate assessment of terrain instability.

Geomorphological Features of Ranchos Palos Verdes

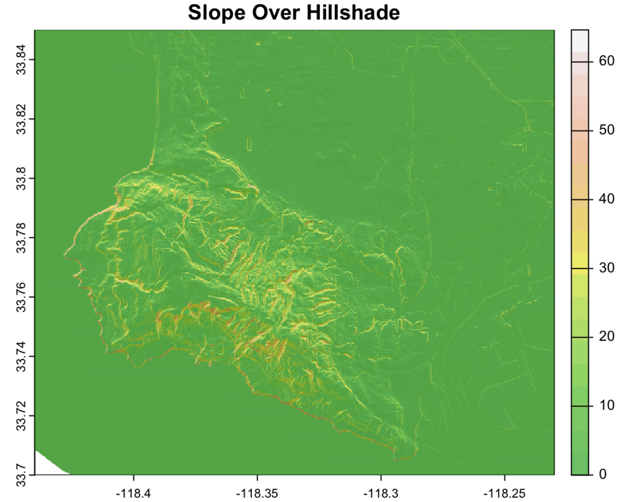
Refined Hillshade



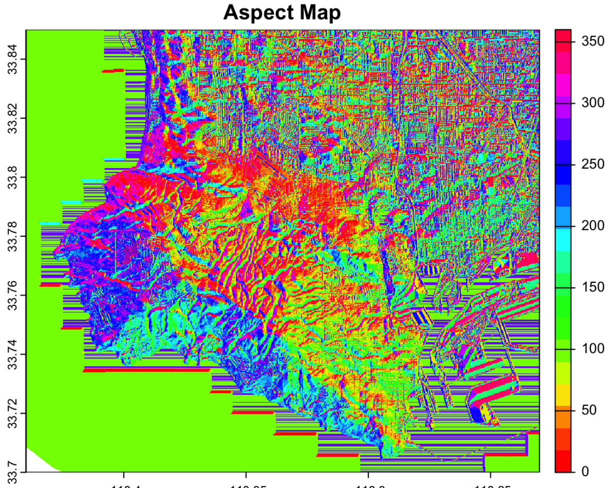
Slope Map



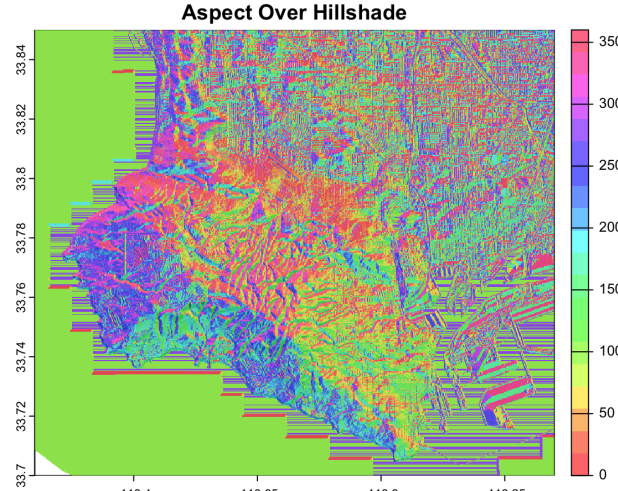
Slope Over Hillshade

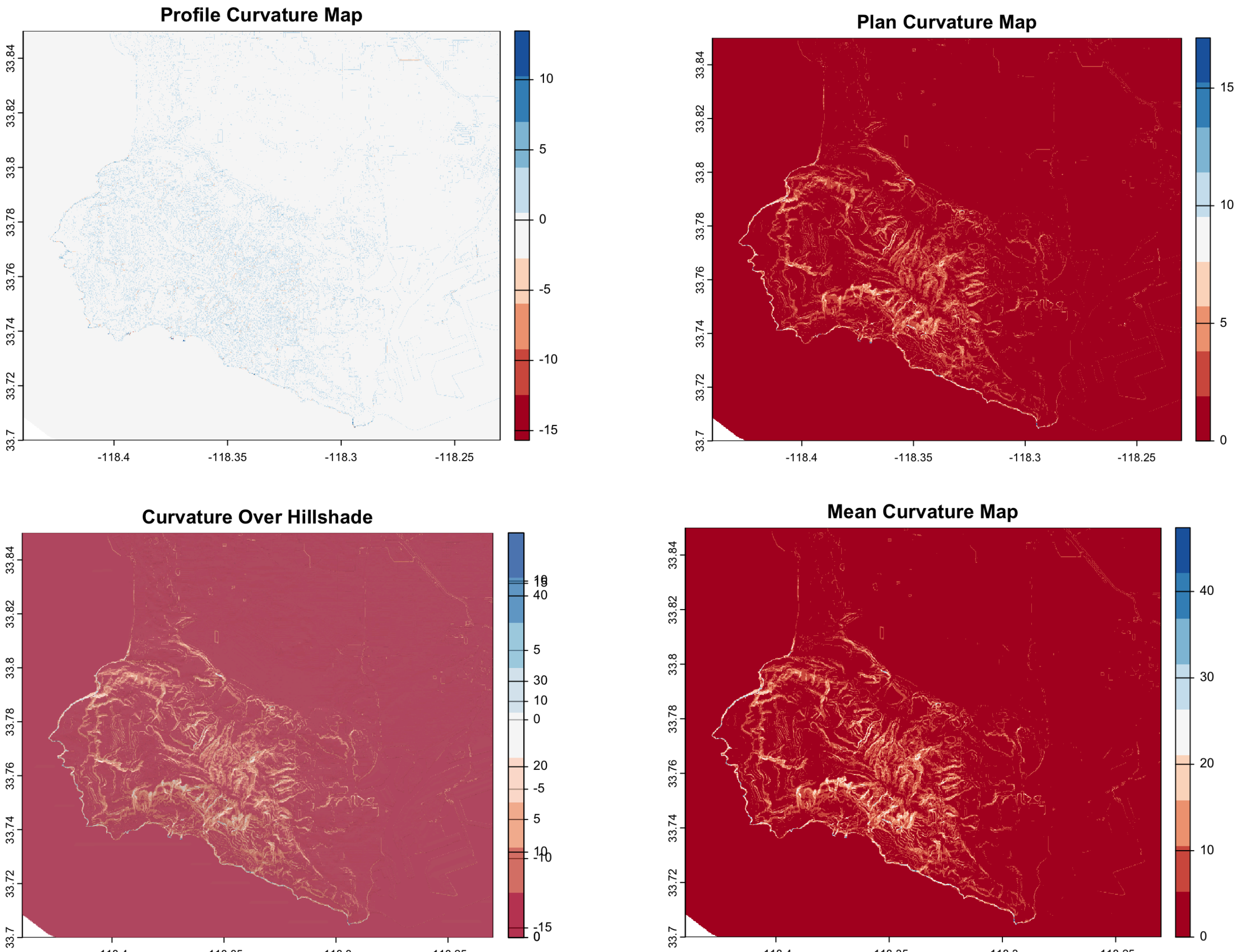


Aspect Map

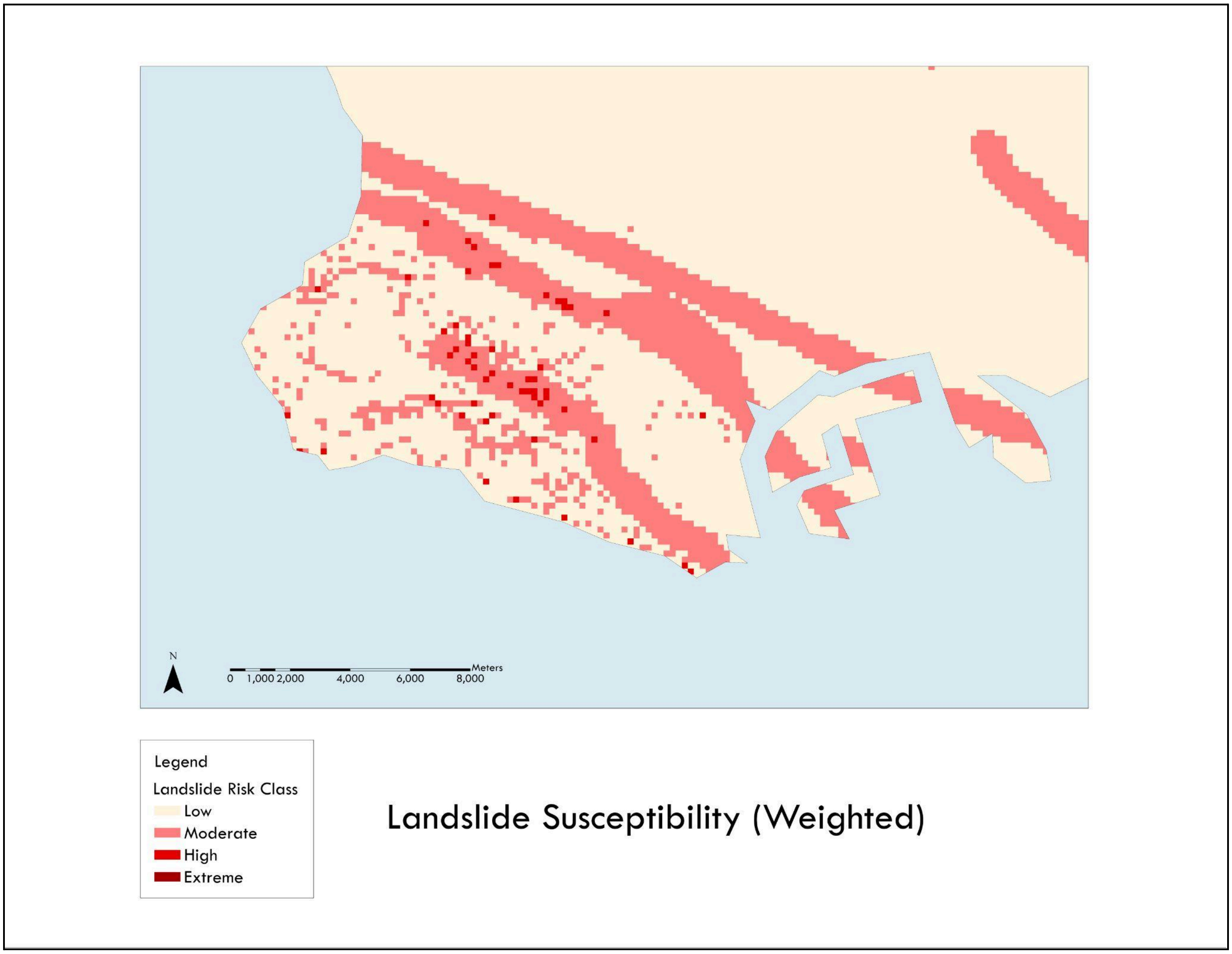


Aspect Over Hillshade




Profile Curvature Map
Plan Curvature Map
Curvature Over Hillshade
Mean Curvature Map
33.7
33.72
33.74
33.76
33.78
33.8
33.82
33.84
-118.4
-118.35
-118.3
-118.25
10
5
0
-5
-10
-15
15
40
30
20

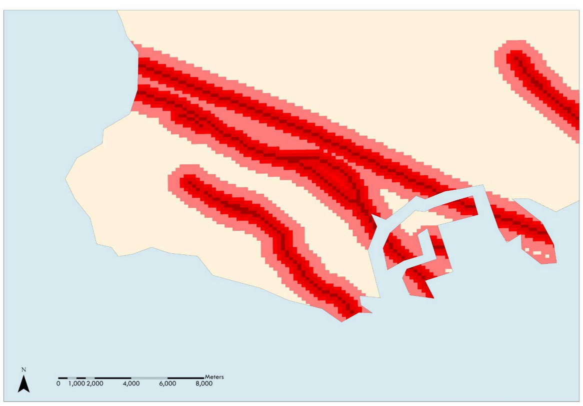
Landslide Susceptibility (Weighted)



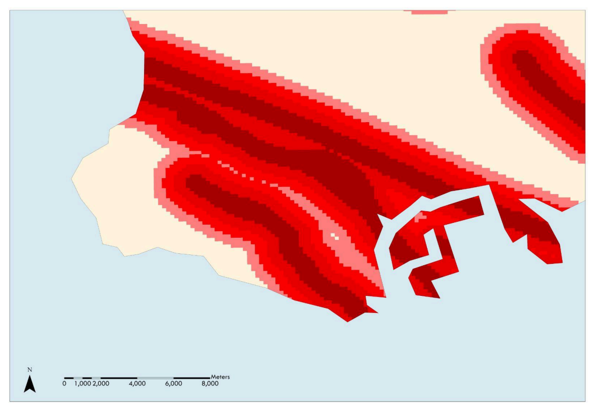
Landslide Susceptibility by Individual Factor

Landslide Susceptibility
Based on Slope Changes

Landslide Susceptibility
Based on Current Slope



Landslide Susceptibility
Based on Drainage Proximity



Landslide Susceptibility
Based on Fault Line Proximity

Works Cited:

Huang, Jianling, et al. “Landslide Susceptibility Evaluation Using Different Slope Units Based on BP Neural Network.” Computational Intelligence and Neuroscience, vol. 2022, 23 May 2022, doi:10.1155/2022/9923775.

U.S. Geological Survey. “3D Elevation Program (3DEP) 1-Meter Digital Elevation Model (DEM).” U.S. Geological Survey ScienceBase Catalog, 2020, https://www.sciencebase.gov/catalog/item/5f77842182ce1d74e7d6c3cb.

U.S. Geological Survey. “Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global Digital Elevation Model (DEM).” U.S. Geological Survey Earth Explorer, 2020, https://earthexplorer.usgs.gov/scene/metadata/full/5e83a3ee1af480c5/SRTM1N33W119V3/.