Appendix A. Procedure to make rockfall susceptibility map for New Mexico using slope-angle criteria

Three steps are associated with making the rockfall susceptibility map presented in Plate 2. The first involves finding representative slopes associated with mapped rockfalls, with consideration of spatial error in the input maps. Then slope-angle criteria are used to define susceptibility classes. The third step entails using these slope-angle classes to create a raster image showing rockfall susceptibility.

Sampling slope values associated with mapped rockfalls

Note: The input map (Cardinali et al, 1990) appears to have errors of 0-600 m based on visual inspection of mapped rockfalls with topographic features. The most useful way to obtain inaccuracy measurements is to note mapped rockfalls that lie on mesa tops but which parallel the mesa top escarpment; these are obviously in error (they should lie below the escarpment, not above it) and it is from these data points that a 0-600 m spatial error is obtained.

The input data is available as an ARC map package in Appendix B.

Interim rasters listed below are archived in a geodatabase (Appendix C).

Input data

1) Mapped rockfall points from Cardinali et al. (1990). We only use naturally occurring rockfalls, excluding rockfalls associated with anthrogenic activity (like road construction).

2) Slope map. This map was produced by down-sampling 4.5-m SPADTM data to 28 m grid size. This data was compiled for the physiographic provinces listed in Open-file Report 594, and were merged together using the "mosaic to new raster" tool in Data Management Tools\Raster Dataset\ Raster\. A slope map was constructed from this 28 m DEM using the "slope" tool in Spatial Analyst Tools\Surface.

Note that the input data are provided as an ARC map package in Appendix B.

Procedure

1). For each rockfall map point, sample the maximum slope value and average slope value within 600 m diameter (300 m radius) circle around that point. The value of 300 m was chosen because that is the average of the spatial error of a map point (error range of 0-600 m).

1a. Make a raster of maximum slope values within a 600 x 600 m rectangle around a given raster grid cell.

Tool: Spatial Analyst Tools\Neighborhood\focal statistics

Input: XX_slope_merge (found in Appendix B)

Neighborhood: rectangle

Height: 600 m (map units)

Width: 600 m (map units)

Statistics Type: Maximum

Output: *DK_FocalStatistics_MaxWin600m2*

1b. Make a raster of average slope values within a 600 x 600 m rectangle a given raster grid cell.

Tool: Spatial Analyst Tools\Neighborhood\focal statistics

Input: XX_slope_merge

Neighborhood: rectangle

Height: 600 m (map units)

Width: 600 m (map units)

Statistics Type: Mean

Output: DK_FocalStatistics_AvgWin600mDiam [note, not included in Appendix C due to large file size]

2) Sample the values underlain by a given mapped rockfall point

2a. What are the maximum slope values?

Tool: Spatial Analyst Tools\Extraction\Sample

Input raster: DK_FocalStatistics_MaxWin600mDiam2

Input point features: BRABB_2ROCK_FALLS_AND_TOPPLES_WGS84_NATURAL

Output table: SlopeValuesOn_MaxWin600mDiam2

Resampling technique: Nearest

2b. What are the average slope values?

Tool: Spatial Analyst Tools\Extraction\Sample

Input raster: DK_FocalStatistics_AvgWin600mDiam

Input point features: BRABB_2ROCK_FALLS_AND_TOPPLES_WGS84_NATURAL

Output table: SlopeValuesOn_AvgWin600mDiam2

Resampling technique: Nearest

3) Export the data from the two tables (SlopeValuesOn_MaxWin600mDiam2 and SlopeValuesOn_AvgWin600mDiam2) to EXCEL tables. Table A-1 is the EXCEL table with the tabulated maximum slope values. Table A-2 is the EXCEL table with the tabulated mean slope values.

4) On the two EXCEL tables, calculate the Median, average, and standard deviation values. Also calculate the mean-less-one standard deviation value, mean-less-two standard deviation values, and the 5th percentile.

5) Plot data distributions of the two tables. The data from taking the maximum value within a 600 m x 600 m rectangle is more normally distributed. So the maximum slope values are chosen (Table A-1). In these data, the average is 29 degrees, the standard deviation is 12 degrees, mean-less-one standard deviation is 17 degrees, and the mean-less-two standard deviations is 5 degrees. The 5th percentile is 8 degrees.

Defining slope-angle threshold values

1) All slope values above the mean-less-one standard deviation of the maximum slope data (≥17°, see above) were assigned as Likely susceptible. These are given a representative integer value of 90.

2) Within a 470 m buffer of a high susceptible area, 5-16° slopes are assigned as Potentially susceptible. These are given a representative integer value of 85. The purpose of this is to capture potential run-out from particularly steep escarpments onto proximal alluvial fans.

3) Outside of the 470 m buffer, 8-16° slopes, coinciding with mean-less-the 5th percentile, are assigned as Potentially susceptible. These are given a representative integer value of 85.

All 0-7° slopes, except those already in a potentially susceptible zone (i.e., within the 470 m buffer), are assigned as Unlikely susceptible. These are given a representative integer value of 83 numerical value.

Producing a raster showing rockfall susceptibility

Input data

1) Mapped rockfall points from Cardinali et al. (1990). We only use naturally occurring rockfalls, excluding rockfalls associated with anthrogenic activity (like road construction).

2) Slope map. This map was produced by down-sampling SPADM data to 28 m grid size. This data was merged together using the "mosaic to New Raster" tool in DataManagement\raster dataset\ raster\. Slope was calculated from this 218 m-resolution DEM using the "Slope tool" in Spatial Analyst\Surface\.

Procedure

1) Extract 17 degree and up slopes from DEM

Tool: Spatial Analyst Tools\Extraction\Extract by Attributes

Input: XX_slope_merge

Where clause: Value>=17

Output: Z:\ARC_fromKoning\Mansell_Work\LandslideRasters.gdb\DK_17AndUp_Slopes

2) Reassign all the 17 degree and up values to a single value corresponding to "Likely susceptible." Likely susceptible integer value is 90.

Tool: Spatial Analyst Tools\Reclass\Reclassify

Input: DK_17AndUp_Slopes

Reclass Field: Value

I used the table on the menu

Output field: DK_Resample_17AndUp_to90

3) Extract 5-16 degree slopes from DEM

Tool: Spatial Analyst Tools\Extraction\Extract by Attributes

Input: XX_slope_merge

Where clause: Value >4 AND Value <17

Output: Z:\ARC_fromKoning\Mansell_Work\LandslideRasters.gdb\Resample_DK_5to16_Slopes

4) Reassign all the 5-16 degree values to a single value corresponding to Potentially susceptible. New value is 85.

Tool: Spatial Analyst Tools\Reclass\Reclassify

Input: DK_5to16_Slopes

Reclass Field: Value

I used the table on the menu

I clicked the option that specifies to change missing values to NoData

Output field: DK_Resample_5to16_slopesEqual85

5) Determine distance of mapped rockfalls from 90-value areas

5a. First find euclidian distance from 90-value areas

Tool: Spatial Analyst Tools\Distance\Euclidian Distance

Input: DK_Resample_17AndUp_to90

Output field: DK_EuclidianDist_fromHighSlopes_NoMax (note: not included in Appendix C due to large file size).

5b. Sample naturally occurring rock falls

Tool: Spatial Analyst Tools\Extraction\Sample

Input raster: DK_EuclidianDist_fromHighSlopes_NoMax

Input point features: Brabb_2ROCK_FALLS_AND_TOPPLES_WGS84_NATURAL

Output TABLE: DistanceOfRockfalls_From17AndUpSlopes

Values were copied-and-pasted into an Excel file presented in Table A-3. DistanceValuesFrom17degreePolygon.xls

I defined outliers as 2*interquartile range, and then did a 90th percentile of these values. This returned 470 m (In Table A-3, see worksheet titled DataWithNoZeroValues_NoOutliers).

5) Create a buffer around Likely susceptible areas; the buffer width is 470 m.

Tool: Distance\Euclidian Distance

Input: DK_Resample_17AndUp_to90

Maximum distance of 470 m

Output field: DK_EuclidianDist_fromHighSlopes_470mMax

6) Reclassify the distances to a single value

Tool: Reclass\Reclassify

Input: DK_EuclidianDist_fromHighSlopes_470mMax

Reclass Field: Value

I clicked the option that specifies to change missing values to NoData

Output field: DK_EuclidianDist_470mMax_SingleValueOf1

7) Extract 5-16 degree data within 470 m of the 17-and-up slopes. Call the output raster "DK_5to16SlopeValuesWithin470mofHigh"

Tool: Extraction\Extract by Mask

Input raster: DK_Resample_5to16_slopesEqual85

Input raster mask: DK_EuclidianDist_470mMax_singleValueOf1

Output raster: DK_5to16SlopeValuesWithin470mofHigh

8) Combine the " DK_5to16SlopeValuesWithin470mofHigh" raster and the Likely susceptible zone raster into a single merged raster.

Tool: DataManagement\raster\raster dataset\mosaic to New Raster

Input rasters: DK_5to16SlopeValuesWithin470mofHigh and DK_Resample_17AndUp_to90

Output raster: DK_Combined_470mMax

Pixel type: 8_bit_unsigned

1 band

Mosaic operator: Sum

9) Combine the "DK_Combined_470mMax" raster and "XX_slope_merge." For overlapping pixels, assign the highest value.

Tool: DataManagement\raster dataset\ raster\mosaic to New Raster

Input rasters: DK_Combined_470mMax and XX_slope_merge

Output raster: DK_Combined_470mMax_all

Pixel type: 8_bit_unsigned

1 band

Mosaic operator: maximum

10) Reassign all the 1-16 degree values outside of buffer to new values representing Unlikely susceptible and Potentially susceptible. Integer representing Potentially susceptible is 85 (for 8-16 degrees slopes). Integer representing Unlikely susceptible is 83 (for 0-7 degree slopes).

Tool: Reclass\Reclassify

Input: DK_Combined_470mMax_all

Reclass Field: Value

Checked option for missing values "go to NoData"

I used the table on the menu

Output raster: DK_Combined_83_85_90

11) Do neighborhood block to capture maximum value within a 500x500 m block

Tool: Spatial Analyst Tool\neighborhood \block statistics

Input raster: DK_Combined_83_85_90

Output raster: DK_Combined_83_85_90_blockstatMax_500m

Rectangle used that was 500 m (map units) on the side.

Ignored NoData in the calculations

I used the 500 m grid size, not the 300 m grid size.

12) Resample to 500 m grid size.

Tool: *Data Management Tools\Raster\Raster Processing\Resample.*

Input: DK_Combined_83_85_90

Output: DK_Combined_83_85_90_Resampled_500m_maj

Resampled technique: Majority

Cell size: 500 m x 500 m

13) Do a majority filter pass

Tool: *Spatial Analyst\generalization\majority filter*

Input: DK_Combined_83_85_90_Resampled_500m_maj

Output: DK_Combined_83_85_90_Resampled_500m_majFilterPass [note: not included in interim rasters of Appendix C, since it is the final product].

Number of neighbors to use: 8

Replacement threshold: half

14) Verify by sampling with mapped natural rock falls

Tool: Spatial Analyst Tools\Extraction\Sample

Input: DK_Combined_83_85_90_Resampled_500m_majFilterPass

Output table: DK_Combined_83_85_90_Resampled_500m_majFilterPass_Stats

Used brabb_2rock_falls_and_topples_WGS84_natural for sampling points.

Sampled using "nearest" technique

Exported data in DK_Combined_83_85_90_Resampled_500m_majFilterPass_Stats to Table A-4. There, a histogram plot was made of the sampled data.