LANDSLIDE HAZARD
IN EL SALVADOR

Carlos Eduardo Rodríguez-Pineda
C.E, MSc, M.G, DIC, PhD

Tatiana Torres
C.E, MSc

Edwin León
C.E, MSc
Content

1. Antecedents
2. Landslide hazard model
3. Application to 13 January, 2001 earthquake
4. Conclusions
Antecedents
Landslide distribution

- Climatically induced landslides are common in the northern mountains and main volcanic chain.
- Earthquake-induced landslides are common in the coastal ranges, main volcanic chain and the interior valley.
- Main landslides types in El Salvador are: Rockfall, Rotational, Translational and Flows
Antecedents
Rainfall-induced landslides

Picacho Landslide

Location: 3 km Nor-West San Salvador

Triggering mechanism:
Three days rain, 17, 18 and 19th September 1982
Volume: 200,000 m3
Type: Debrisflow
Antecedents
Earthquake-induced landslides

Triggering mechanism:
January 13, 2001,
Magnitud 7.6
Volume:
150,000 m³.
Type: Complex.
Proposed Model
Rodríguez (2001)

\[ H_s = T \cdot S \]
Proposed Model
Rodríguez (2001)

Susceptibility function

\[ S_{Mi} = \frac{W - W_{\text{min}}}{W_{\text{max}} - W_{\text{min}}} \]

\[ W = W_L + W_S + W_{Ca} + W_{Cm} \]

\[ W_L = W_{Li} \cdot W_{Lj} \]
\[ W_S = W_{Si} \cdot W_{Sk} \]
\[ W_{Ca} = W_{Cai} \cdot W_{Cal} \]
\[ W_{Cm} = W_{Cmi} \cdot W_{Cmm} \]
Proposed Model
Rodríguez (2001)

Susceptibility function

<table>
<thead>
<tr>
<th>Weighting factors for lithology units</th>
<th>Factor $W_{Li}$</th>
<th>Valor</th>
<th>Factor $W_{Lj}$</th>
<th>Valor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{L1}$</td>
<td>0.583</td>
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<td>$W_{L2}$</td>
<td>0.445</td>
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<tr>
<td>$W_{L2}$</td>
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<td>$W_{L3}$</td>
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<tr>
<td>$W_{L3}$</td>
<td>0.166</td>
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<td>$W_{L4}$</td>
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<td>$W_{L5}$</td>
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<td></td>
<td>$W_{L6}$</td>
<td>0.347</td>
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</table>

<table>
<thead>
<tr>
<th>Weighting factors for slope angle</th>
<th>Factor $W_{Si}$</th>
<th>Valor</th>
<th>Factor $W_{Ca1}$</th>
<th>Valor</th>
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<tbody>
<tr>
<td>$W_{Si}$</td>
<td>0.470</td>
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<td>$W_{Ca1}$</td>
<td>0.012</td>
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<tr>
<td>$W_{S2}$</td>
<td>0.095</td>
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<td>$W_{Ca2}$</td>
<td>0.010</td>
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<td>$W_{S3}$</td>
<td>0.435</td>
<td></td>
<td>$W_{Ca3}$</td>
<td>0.046</td>
</tr>
<tr>
<td>$W_{S4}$</td>
<td></td>
<td></td>
<td>$W_{Ca4}$</td>
<td>0.104</td>
</tr>
<tr>
<td>$W_{Ca5}$</td>
<td></td>
<td></td>
<td>$W_{Ca5}$</td>
<td>0.828</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Weighting factors for annual rainfall</th>
<th>Factor $W_{Ca1}$</th>
<th>Valor</th>
<th>Factor $W_{Ca1}$</th>
<th>Valor</th>
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<tbody>
<tr>
<td>$W_{Ca1}$</td>
<td>0.492</td>
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<td>$W_{Ca1}$</td>
<td>0.012</td>
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<tr>
<td>$W_{Ca2}$</td>
<td>0.334</td>
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<td>0.010</td>
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<tr>
<td>$W_{Ca3}$</td>
<td>0.174</td>
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<td>$W_{Ca3}$</td>
<td>0.046</td>
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<tr>
<td>$W_{Ca4}$</td>
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<td>$W_{Ca4}$</td>
<td>0.104</td>
</tr>
<tr>
<td>$W_{Ca5}$</td>
<td></td>
<td></td>
<td>$W_{Ca5}$</td>
<td>0.828</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weighting factors for monthly rainfall</th>
<th>Factor $W_{Ca1}$</th>
<th>Valor</th>
<th>Factor $W_{Ca1}$</th>
<th>Valor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{Ca1}$</td>
<td>0.491</td>
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<td>$W_{Ca1}$</td>
<td>0.208</td>
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<tr>
<td>$W_{Ca2}$</td>
<td>0.335</td>
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<td>$W_{Ca2}$</td>
<td>0.244</td>
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<tr>
<td>$W_{Ca3}$</td>
<td>0.174</td>
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<td>$W_{Ca3}$</td>
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<tr>
<td>$W_{Ca5}$</td>
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<td></td>
<td>$W_{Ca5}$</td>
<td>0.054</td>
</tr>
</tbody>
</table>
Proposed Model
Rodríguez (2001)

Triggering function

\[ T = \frac{SP - SP_{\text{min}}}{SP_{\text{max}} - SP_{\text{min}}} \]
Application
January 13, 2001 earthquake

Lithology
Application
January 13, 2001 earthquake

Topography
Application
January 13, 2001 earthquake

Annual rainfall
Application
January 13, 2001 earthquake

Monthly rainfall
Application
January 13, 2001 earthquake
Peak Ground Acceleration
Application
January 13, 2001 earthquake

Susceptibility and Triggering intervals
**Application**
**January 13, 2001 earthquake**

**Susceptibility and Triggering intervals**

<table>
<thead>
<tr>
<th>Level</th>
<th>Triggering Function (Based on PGA)</th>
<th>Susceptibility Function (For disrupted slides)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>0-0.075</td>
<td>0-0.36</td>
</tr>
<tr>
<td>Low</td>
<td>0.075-0.185</td>
<td>0-0.36</td>
</tr>
<tr>
<td>Medium</td>
<td>0.185-0.355</td>
<td>0.36-0.67</td>
</tr>
<tr>
<td>High</td>
<td>0.355-0.482</td>
<td>0.67-0.79</td>
</tr>
<tr>
<td>Very High</td>
<td>0.482-1.0</td>
<td>0.79-1.0</td>
</tr>
</tbody>
</table>
Application
January 13, 2001 earthquake

Susceptibility
Application
January 13, 2001 earthquake

Triggering
Application
January 13, 2001 earthquake

Landslide hazard
Application
January 13, 2001 earthquake

Landslide hazard- Mora and Vahrson
Conclusions

- Earthquake- and rainfall-induced landslides in El Salvador start mainly as disrupted slides and falls in residual, alluvial, volcanic-ash, and volcanic-rock deposits.
- When the intensity of the triggering events is sufficient to induce large displacements, or the soils are sufficiently contractive, landslides can transform into debris flows that travel long distances. As a result initially small, isolated events can have consequences that reach far beyond their immediate source area.
- Spatial distribution of these slides is controlled by topographic, climatic and seismicity distribution around the country.
Conclusions

- Temporal occurrence is controlled by the rainfalls and earthquakes sequences. Precedent rainfalls, particularly shows a strong influence on intensity of rainfall or seismic events able to induce failures.

- Spatial and temporal variability can be considered in landslide hazard analysis by taken models which include local and regional conditions as that proposed by Mora and Vahrson, however care must be taken when applying this model which was developed under different conditions than those present in El Salvador.

- The proposed model shows better results in defining spatial distribution of landslide hazard however important improvements are needed in order to improve predictions, particularly weighting values for different variables must be review in order to avoid overestimation on gentle slope of susceptible soils.