Using TRMM precipitation estimates to understand landslide occurrence in Papua New Guinea

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With thanks to the University of Leicester and the University of Papua New Guinea
Overview of presentation

• Background: Physiographical overview & rainfall-induced landslides

• Background: landslide-triggering rainfall event threshold development

• Overview of Method
  • Identifying rainfall events for landslides & non-landslides
  • Identifying rainfall event thresholds for landslides: Bayesian approach

• Probabilistic rainfall thresholds: results
Physiographical overview of Papua New Guinea

Abbreviations:
NBP – North Bismarck Plate
SBP – South Bismarck Plate
SSP – Solomon Sea Plate
WP – Woodlark Plate
Triggers & causative factors for landslides in Papua New Guinea
Larger rainfall accumulations can:

- increase water loading
- cause water tables to rise
- reduce sliding resistances as pore pressures increase
- lead to increases in surface runoff and river flow velocities
- result in surface erosion and river undercutting

Variations in rainfall can also mobilize shrink-swell processes in certain geological materials.
Commonly derived empirically-based rainfall thresholds include:

- **intensity-duration** (ID) thresholds
- thresholds based on the total event rainfall
- **rainfall event-duration** (ED) thresholds
- **rainfall event-intensity** (EI) thresholds

Potential issues with conventional techniques:

- they frequently *do not account for the climatology* of different magnitude-duration rainfall events
- Predominantly used for *shallow landslides* induced by short-duration, high-intensity rainfall
- *subjectively identify/define rainfall events*
- *subjectively identify linear threshold* based on rainfall events associated with landslides only
- majority are developed through a *deterministic* framework

Landslide-triggering event inventory

Landslide-triggering event is a meteorological, geological or hydrological event/hazard which led to landslides.

Landslide Types
*1 Landslide type images courtesy of USGS from their website: http://pubs.usgs.gov/fs/2004/3072/images/Fig3grouping-2LG.jpg
*2 MRA = Mineral Resources Authority in PNG
*3 DMPGM = Department of Mineral Policy and Geohazards Management

Triggering event meta-data sources
(1) Technical/Site inspection reports (PNG MRA*2 & DMPGM*3)
(2) Journal publications
(3) Newspaper records
(4) Internet publications (ReliefWeb)
(5) Supplementary archives (Dartmouth Flood Observatory, USGS Earthquake Catalogue)
Identifying rainfall events: representative rainfall for landslide events using TRMM
Identifying rainfall events: determining critical rainfall durations

The ‘multiple time frames’ method has been used – this aims to truncate a rainfall time series into discreet events based on a number of different rainfall durations.

<table>
<thead>
<tr>
<th>Time intervals used in this study</th>
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<tr>
<td>5 days</td>
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<td>10 days</td>
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<td>15 days</td>
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<td>75 days</td>
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<td>90 days</td>
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Rainfall event is characterised by variables such as accumulation, intensity and/or duration. In intensity-duration or accumulation-duration analysis the rainfall event is defined by the critical rainfall start date and the critical rainfall end date. The number of days between these two critical points equals the critical rainfall duration.

Important time intervals (days) and the associated hydrologic systems & conditions that may induce landsliding

From Fuhrmann et al. (2008). Physical Geography, 29, 289-305
Identifying rainfall event thresholds: log-log plots

* log accumulation – log duration plot
* log Intensity – log duration plot

Blue and red lines are used as approximate, preliminary separators of the data across the different durations.
Identifying probabilistic rainfall event thresholds: Bayesian approach

\[ P(A|B, C) = \frac{P(B, C|A) \cdot P(A)}{P(B, C)} \]

- \( P(B, C|A) \) is the conditional probability of \( B \) (rainfall event of certain magnitude) & \( C \) (rainfall event of certain duration) given \( A \) (landslides)
- \( P(A) \) is the prior probability
- \( P(B, C) \) is the marginal probability & represents the probability of observing \( B \) & \( C \) (regardless of whether \( A \) occurs or not)
- \( P(A|B, C) \) is the posterior probability of \( A \) given \( B \) & \( C \)
Identifying probabilistic rainfall event thresholds: Results

Landslide probabilities as a function of accumulation-duration (left) and intensity-duration (right).

Probabilities refer to any 0.25 x 0.25 TRMM grid square, from the 40 representative grid squares where landslides have previously been identified.
Applications, uncertainties & assumptions

Staggered warning system based on different probability thresholds

Needs to take **account of community vulnerability & resilience** which is spatially variable

Requires **collaboration & leadership from in-country experts** to ensure forecasts are applicable & integrated within existing policies & procedures so that hazard mitigation and response can be effective

This method is dependent on the **process used to categorise rainfall events** associated with landslides and non-landslides, the **completeness & extent of the landslide inventory** & the **length, completeness and biases associated with the TRMM data used.**

Does not account for spatial variability associated with landslide environmental control factors (eg. topographical (slope, aspect) & lithological (rock types, lithology))
Future Developments & Concepts

Conceptual model framework for landslide susceptibility warning/forecasting

DYNAMIC RAINFALL DATA

STATIC ENVIRONMENTAL CONTROL FACTOR DATASETS (eg. slope, lithology, etc.)

Combine dynamic data and static susceptibility (eg. fuzzy logic)

Spatial & temporal warnings of increased landslide susceptibility and landslide activity
Questions?
Acknowledgements

This research was jointly supported by the Met Office, University of Leicester and the University of Papua New Guinea.

Special thanks go to colleagues at the PNG Mineral Resources Authority (MRA) and the Department of Mineral Policy and Geohazards Management in Papua New Guinea for their help and support throughout the completion of this research.