Monitoring rainfall-induced failures in Glen Ogle, Scotland

Charlie Gilles, Trevor Hoey and Richard Williams
School of Geographical and Earth Sciences,
University of Glasgow
Landslide impacts

- Costing globally $4 billion per annum
- > 16.5 k recorded in UK since 1970s
- 34% Scottish road network at risk

- Rest & Be Thankful
  - 2007
  - 2009
  - 2011
  - 2012

- Closure of A83
- Cost ~ £13.5 million in mitigation so far
Landslide monitoring techniques

Coverage
• Regional – remote sensing (eg InSAR)
• Hillslope (eg TLS)
• Local (eg sensors)

Point density
Glen Ogle

- 150 m asl valley floor
- Neighbouring peaks 600 m
- Mean slope 47°
- Mean annual rainfall 1400 mm
- 18th August 2004- 80 mm of rain, peak intensity of 20 mm hr⁻¹
- In the preceding 10 days rainfall total 90 mm
- The 18th August event generated 31 debris flows across Glen Ogle
Soil Saturation Index

- Modelled soil saturation - effective precipitation 29 mm/day; uniform soil thickness = 1 m
- Saturated soils - purple
  unsaturated - yellow
- Glen Ogle - yellow circle
- O’Loughlin (1986)
Glen Ogle area

- SSI indicates areas of landslide susceptibility
- Study area in yellow circle
Geological setting

• Neoproterozoic bedrock, Ben Lui Schist formation (BGS)
• Overlain by Quaternary glacial deposits
• Diamict peat rich soil <2 m
• Some normal faulting
Methods

• Multi-sensor approach sensor network
• Area of interest (10 m by 15 m; failure and adjacent control slope) in yellow
• TLS
• Weather station
• IMU sensors
• Soil moisture probe.
TLS workflow

- 3 field campaigns October 2016-present
- Max scanning distance 1.4 km
- Field of view 3 km²
- Three scanning positions
- Six 150 mm targets
- Targets and scan positions spaced over ~900 m
- Mean density 39 points.m⁻²
- RMS error 0.28m
2016 raw merged point cloud (3km$^2$)
Rainfall Aug 2016 – Sept 2017

- Daily rainfall from SEPA weather station at Glen Ample (9 km from Glen Ogle)
- Monthly totals from SEPA data (green)
- Monthly maximum, minimum and mean (dashed lines) rainfall for West of Scotland (WofS), from Met Office data
- Orange boxes TLS scan dates
2016/17 DEM of Difference (DoD)

- Surface elevation change from October 2016 to March 2017

Blue - Sediment Loss.
Red - Sediment Gain.
No fill - negligible change
IMU sensors

- Wireless remote platform
- 3 axis accelerometer
  - +/- 4 g range
- Gyroscope
  - 200° s\(^{-1}\) sensitivity
- Nominal sampling frequency 50 Hz
- Specially designed aluminum housing
- Designed for high speed entrainment in rivers and coasts
IMU calibration

Artificial pebble sliding under gravity on a sand soil

Repeated 10 times recording data at each of:
50 Hz
30 Hz
20 Hz
10 Hz
IMU 10 Hz data

Finely filtered

Coarsely filtered
Integrating methods
Conclusions

• TLS method validated over a large spatial scale (1.5 km) with vertical errors of ± 0.28 m
• First DoD shows a maximum surface elevation change of ± 1 m
• Limited change in the DoD is due to an absence of large rainfall events between the scans
• DEM and SSI suggest how topography influences landslide susceptibility
• Sensor sampling at 10Hz identifies displacement events
Thank you